UNCLASSIFIED

AD NUMBER
AD030281
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Controlling DoD Organization: Picatinny Arsenal, Dover, NJ 07801.
AUTHORITY
Army Armament R&D Comd ltr dtd 13 Feb 1980; Army Armament R&D Comd ltr dtd 13 Feb 1980

THIS PAGE IS UNCLASSIFIED

AD 30281

CONFIDENTIAL

NOTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794. THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

PICATINNY ARSENAL

TECHNICAL DIVISION

TECHNICAL REPORT

SUBJECT: EVALUATION OF 4-NITRO-N-METHYLANILINE FOR USE AS A STABILIZER IN DOUBLE-BASE ROCKET PROPELLANTS

ORDNANCE
PROJECT NO. TU2-2C
(FORMERLY TU2-3A)

DEPT. OF THE ARMY
PROJECT NO. 517-06-003

PREPARED BY: J. M. SWOTINSKY

DATE: APRIL 1954

P. A. SERIAL NO. 2009

COPY NO. 00062

EVALUATION OF 4-NITRO-N-METHYLANILINE FOR USE AS A STABILIZER IN DOUBLE-BASE ROCKET PROPELLANTS

by

J. M. Swotinsky

April 1954

Picatinny Arsenal

Dover, N. J.

Technical Report 2009

Ordnance Project TU2-2C
(formerly TU2-3A)

Dept of the Army Project 517-06-003

Approved:

JOHN D. ARMITAGE
Col, Ord Corps
Chief, Technical Div

OBJECT

To determine the improvement in the stability characteristics of double-base rocket propellants that can be obtained by the use of 4-nitro-N-methylaniline as a stabilizer.

SUMMARY

The initial investigation on the use of 4-nitro-N-methylaniline as a stabilizer for double-base propellants was conducted by determining the stability characteristics of T16 Propellant manufactured with ethyl centralite, 2-nitrodiphenylamine, and 4-nitro-N-methylaniline both alone and in combination with each other. Short term stability tests revealed the vast superiority of 4-nitro-N-methylaniline over ethyl centralite, which is the standard stabilizer in T16 Propellant, and 2-nitrodiphenylamine with no adverse effect upon the processing, ballistic, and physical properties.

The use of a combination stabilizer consisting of 1% 4-nitro-N-methylaniline plus 1% ethyl centralite increased the storage life of thick web grains (5 inches OD by 1 inch ID by 10 inches long) at 170°F. twofold for T16 Propellant and threefold for T19 Propellant. Furthermore, the resistance to thermal shock between -75°F. and 170°F. for these thick web geometries markedly increased for T19 Propellant and improved to a lesser degree for T16 Propellant. Although strand ballistic data on several lots of T16 and T19 Propellants containing the combination stabilizer exhibited slightly higher temperature coefficients than normal while maintaining a mesa-type burning rate versus pressure relationship, further investigation revealed that the substitution of 1% 4-nitro-N-methylaniline for 1% ethyl centralite in the two rocket propellants under consideration did not detract from the low temperature coefficient, mesa-type ballistics characteristic of these two formulations.

CONCLUSIONS

It is concluded that the replacement of ethyl centralite as the stabilizer in T16 and T19 Propellants with a combination stabilizer consisting of half (1%) ethyl centralite plus half (1%) 4-nitro-N-methylaniline greatly improved the chemical stability, storage life, and cyclic life of both compositions without vitiating the low temperature coefficient, mesa-type ballistics normally associated with these two formulations.

RECOMMENDATIONS

It is recommended that:

a. Pending the successful completion of static firing tests which are currently being conducted with Pilot Lot Nos. 334 and 335 to further establish the ballistic characteristics, consideration be given to modifying the compositions and specifications for T16 and T19 Propellants by substituting 1% 4-nitro-N-methylaniline for 1% ethyl centralite in each formulation.

b. A specification be prepared covering 4-nitro-N-methylaniline.

c. Both T16 and T19 Propellants amended by the utilization of a combination stabilizer consisting of 1% 4-nitro-N-methylaniline plus 1% ethyl centralite be subjected to long-term testing under Project No. TU2-4D (Storage Stability of Rocket Propellants).

d. Consideration be given to determining by tests if the incorporation of 4-nitro-N-methylaniline in other double-base rocket propellants currently in use can impart comparable improvements.

INTRODUCTION:

1. Although the safe life of a propellant as related to the point of spontaneous decomposition is sufficiently long even at elevated temperatures for all standard double-base rocket formulations, the safe life period of large-web grains is considerably shorter due to the formation of cracks. This cracking is a result of the gas pressure created by the decomposition products of the propellant. Although no cracking problems arise in the case of thin-web grains because the decomposition gases evolved at elevated temperatures easily diffuse through the propellant, thick-web grains crack quite readily when subjected to accelerated high temperature storage conditions. Consequently, this Arsenal is continuously searching for new stabilizers for rocket propellants that postpone cracking for thick-web geometries.

2. Basic research by the U.S. Naval Powder Factory as reported in Semi-Annual Report 1, 1 July 1950 - 31 December 1950, showed that nearly all N-substituted aromatic nitramines are good stabilizers except the 2-nitro-N-alkyl anilines. One of the reasons found for this superiority of the nitro-aromatic secondary amines is that their affinity for nitrogen dioxide is very great and the reaction between nitrogen dioxide and stabilizer is rapid and complete, so that no nitric oxide is formed. In the case of ethyl centralite, diphenylamine, and acardite, substantial amounts of nitric oxide are formed on exposure of these stabilizers to nitrogen dioxide. Furthermore, the nitro group to some extent neutralizes the secondary amine, forming a neutral compound that is compatible with nitrocellulose. It is not evident from the work performed which nitro-aromatic secondary amine gives the best stabilizing efficiency. However, based upon short-term chemical stability tests it was indicated that 4-nitro-N-methylaniline imparted excellent stability properties to double-base propellants when incorporated in small concentrations.

3. This report covers the evaluation of 4-nitro-N-methylaniline in T16 and T19 Propellants, both of which are newly developed mesa-type, double-base rocket propellants. Although these two formulations exhibit good stability characteristics, with T16 Propellant superior to the T19 Formulation, work was conducted with these two compositions toward increasing the storage life based on the ability of 4-nitro-N-methylaniline to completely remove the oxides of nitrogen propellant decomposition products.

4. The 4-nitro-N-methylaniline utilized in this investigation was procured from the Eastman Kodak Company. The properties of this material are outlined in Table 1.

RESULTS:

5. The results of incorporating various combinations of ethyl centralite, 2-nitrodiphenylamine, and 4-nitro-N-methylaniline as the stabilizer in T16 Propellant (Pilot Lot Nos. 144-149) are summarized below. The specific compositions, and stability, ballistic, physical, and processing properties data are tabulated in Table No. 2. Figures 1 through 6 represent a logarithmic plot of the strand burning-rate versus pressure for each of the six compositions.

a. The use of 4-nitro-N-methylaniline alone or in conjunction with either ethyl centralite or 2-nitrodiphenylamine exhibited excellent stability characteristics as evidenced by the short-term stability tests employed. The 65.5°C. surveillance test has been in progress for all six compositions since January 1952; however, no end-point has been reached to date.

b. Replacement of part or all of the ethyl centralite currently used in T16 Propellant with either 2-nitrodiphenylamine or 4-nitro-N-methylaniline or combinations thereof did not adversely affect the low temperature coefficient, mesa-type strand burning-rate characteristics.

c. Low-rate compression and tension tests indicated that the use of stabilizers other than ethyl centralite in T16 Propellant resulted in physical properties comparable to standard T16 Propellant.

6. The results of incorporating a combination stabilizer consisting of 1% 4-nitro-N-methylaniline plus 1% ethyl centralite in T16 and T19 Propellants are summarized below. The specific compositions, and stability, accelerated storage, cyclic ballistic, and processing characteristics for Pilot Lot Nos. 334, 334A, 334A1, 334B, 335, and 335A are tabulated in Table No. 3 in comparison to standard T19 and T16 Propellants (Pilot Lot Nos. 276B (and A) and Slurry No. 614, respectively). The strand burning-rate versus pressure is plotted in Figures 7-15. Photographs of the propellant grains for Pilot Lot Nos. 334, 335, 276B, and Slurry No. 614 after completion of the accelerated storage and

cyclic tests are given in Photos. M-42406/3, M-42406/5, M-42406/1, M-42931, M-42933, M-42930, and M-42932.

a. The short-term stability test results for the two T16 Propellant lots containing the combination stabilizer (Pilot Lot Nos. 335 and 335A) confirmed the excellent stability characteristics obtained in the initial investigation of 4-nitro-N-methylaniline in T16 Propellant (Pilot Lot Nos. 144-149).

b. The addition of 4-nitro-N-methylaniline to T19 Propellant (Pilot Lot Nos. 334, 334A, and 334B) greatly improved the stability characteristics as evidenced by the short-term stability tests employed. The excellent stability data obtained were comparable to those exhibited by T16 Propellant containing the new stabilizer, with the latter composition still remaining slightly better than the similarly modified T19 Propellant.

c. The accelerated storage and cyclic characteristics for both the T19 and T16 Propellants modified by the inclusion of 4-nitro-N-methylaniline (Pilot Lot Nos. 334 and 335) were far superior to the basic formulations containing ethyl centralite as the stabilizer. The time to cracking at 170°F. was increased from 4 days to 11 days for T19 Propellant and from 10 days to 18 days for T16 Propellant. In the shock-cycle test conducted between -75°F. and 170°F. the number of cycles to cracking was increased from 3½ cycles to 8 cycles for T19 Propellant and from 9 cycles to 12 cycles for T16 Propellant.

d. The strand burning-rate data revealed that although both Pilot Lot Nos. 334 and 335 exhibited mesa-type ballistics, the optimum temperature coefficients of 0.13% and 0.17% /°F. were somewhat higher than the comparable standard formulations.

e. The remanufacture of T19 and T16 Propellants (Pilot Lot Nos. 334A, 334B, and 335A) resulted in mesa-type strand ballistics and optimum temperature coefficients of 0.12%, 0.03%, and 0.11% /°F., respectively. The last two values of temperature coefficient are in accord with the characteristics of the standard formulations, whereas the value of 0.12% /°F. for Pilot Lot No. 334A is somewhat higher than the accepted value of 0.05% /°F. for T19 Propellant.

f. Reworking of Pilot Lot No. 334A (Pilot Lot No.

334A1) resulted in low temperature coefficient (0.06% /°F.), mesa-type ballistics, characteristic of T19 Propellant.

DISCUSSION:

7. The initial investigation on the use of 4-nitro-N-methylaniline as a stabilizer for double-base rocket propellants was conducted with T16 Propellant, which is the most promising rocket propellant being used in Ordnance applications. The basic T16 formulation, which contains 2% ethyl centralite as the stabilizer, was modified by the substitution of 2-nitrodiphenylamine and 4-nitro-N-methylaniline for half or all of the ethyl centralite. It was also modified [redacted] by the use of a combination of 2-nitrodiphenylamine and 4-nitro-N-methylaniline as a replacement for all the ethyl centralite. The selection of 2-nitrodiphenylamine for inclusion in the investigation was made because both ethyl centralite and 2-nitrodiphenylamine are currently recognized as standard stabilizers for rocket propellants. For those compositions containing 4-nitro-N-methylaniline either alone or in conjunction with ethyl centralite or 2-nitrodiphenylamine (Pilot Lot Nos. 146, 147 and 149), analysis of the 120°C. heat test, the 90°C. vacuum stability test, and the 110°C. Taliani test revealed that the stability characteristics of T16 Propellant were greatly enhanced by the presence of this compound. The values obtained in all three stability tests employed were far superior to the data obtained for standard T16 Propellant (Pilot Lot No. 144 - control lot) containing 2% ethyl centralite and T16 Propellant manufactured with 2-nitrodiphenylamine (Pilot Lot No. 148) or a combination of ethyl centralite plus 2-nitrodiphenylamine (Pilot Lot No. 145). Furthermore, the modification in stabilizer in all cases did not adversely affect the low temperature coefficient, mesa-type ballistics associated with T16 Propellant nor did it adversely affect the physical properties of T16 Propellant.

8. Based on the ability of 4-nitro-N-methylaniline to more completely remove the decomposition products of the propellant than ethyl centralite as indicated by the 90°C. vacuum stability test and the 110°C. Taliani test, where the gas evolved is considerably less than that evolved from the control lot, further work was conducted by manufacturing thick-web grains of both T19 and T16 Propellants (Pilot Lot Nos. 334 and 335) containing 1% 4-nitro-N-methylaniline plus 1% ethyl centralite to determine the time to cracking under accelerated storage and cyclic conditions.

The combination stabilizer was selected in preference to the use of 4-nitro-N-methylaniline alone because ethyl centralite is a tried and proven stabilizer capable of imparting chemical stability to double-base propellants over a long period of time. Consequently, it was desired to combine the ability of 4-nitro-N-methylaniline to react more completely with the oxides of nitrogen decomposition products of double-base propellants with the aforementioned desirable properties of ethyl centralite.

9. The stability characteristics for both T19 and T16 Propellants containing half ethyl centralite plus half 4-nitro-N-methylaniline (Pilot Lot Nos. 334 and 335) were far superior to the standard compositions as evidenced by all three chemical stability tests employed. The excellent chemical stability characteristics attainable through the use of 4-nitro-N-methylaniline were demonstrated to hold true for T19 as well as T16 Propellant. The days to cracking at 170°F. were increased almost threefold for T19 Propellant and twofold for T16 Propellant. Thus it is apparent that the utilization of a 4-nitro-N-methylaniline plus ethyl centralite combination stabilizer imparts both resistance to cracking for thick-web grains under elevated storage plus excellent chemical stability over and above the good stability characteristics currently exhibited by T19 and T16 Propellants by more completely reacting with the gases evolved. In addition, the number of cycles to cracking between -75°F. and 170°F. was substantially increased for T19 Propellant and improved to a lesser degree for T16 Propellant. This improvement in the resistance to thermal shock is in accordance with the improvement obtained in the time to cracking at elevated temperature storage conditions by the substitution of 1% 4-nitro-N-methylaniline for 1% ethyl centralite in both T19 and T16 Propellants. This indicates that the ability of 4-nitro-N-methylaniline to react rapidly with the propellant decomposition products during the high temperature storage phase of shock-cycling is a factor in improving the resistance to thermal shock.

10. The strand ballistic data for Pilot Lot Nos. 334 and 335 indicated that the replacement of 1% ethyl centralite by 1% 4-nitro-N-methylaniline did not interfere with the mesa-type ballistics normally associated with T19 and T16 Propellants. In both lots there was a larger spread than normal between the low temperature and the high temperature burning-rate curve. However, it does not appear that this difference in ballistics is attributable

to the modification in stabilizer, because the control lot for T19 Propellant (Pilot Lot No. 276B) which was manufactured at the same time behaved in the same manner. Furthermore, initial investigation of 4-nitro-N-methylaniline in T16 Propellant did not alter the ballistics of T16 in any respect. Investigation into the reason for the somewhat higher temperature coefficient in Pilot Lot Nos. 276B, 334, and 335 revealed that a new lot of nitrocellulose was used for the first time in the manufacture of the three lots in question. Subsequently, several other batches of propellant manufactured from this lot of nitrocellulose also exhibited higher temperature coefficients than normal, thus indicating that the particular lot of nitrocellulose may have been the cause of the difficulty.

11. The discrepancy in the strand ballistic results with regard to the slightly higher temperature coefficients exhibited by Pilot Lot Nos. 276B, 334, and 335 was investigated further by remanufacturing the last two compositions with another lot of nitrocellulose and designating them as Pilot Lot Nos. 334A and 335A. Pilot Lot No. 335A reproduced typical T16 Propellant, mesa-type, low temperature coefficient strand burning-rate characteristics. Although Pilot Lot No. 334A exhibited good mesa-type, strand burning-rate characteristics at a burning-rate level of 0.5 ips on the plateau portion of the mesa, the -40°F. isotherm was rather low, thus resulting in an optimum temperature coefficient of 0.12% /°F., which was somewhat greater than the value of 0.05% /°F. normally obtained for T19 Propellant.

12. In an effort to determine whether the poor low temperature ballistics obtained for Pilot Lot No. 334A may have been caused by an inferior distribution of lead salts, the remaining propellant grains were cut into wafers, rolled into even-speed sheets, and extruded in a 4-inch solventless press in an attempt to further distribute the ballistic modifiers. The extruded propellant was designated as Pilot Lot No. 334A1. At the same time another lot of T19 Propellant modified by the incorporation of a combination stabilizer consisting of 1% ethyl centralite plus 1% 4-nitro-N-methylaniline was manufactured and designated as Pilot Lot No. 334B for ballistic evaluation. The strand burning-rate data for Pilot Lot No. 334A1 revealed a definite increase in the burning-rate level of the -40°F. isotherm without any modification in the burning characteristics at room and elevated temperatures. This resulted in an optimum temperature coefficient

of pressure of 0.06% /°F., which was almost equivalent to that of standard T19 Propellant. Thus it was apparent that an inadequate distribution of lead salts did exist in Pilot Lot No. 334A and that further working of this propellant both on the rolls and in the extrusion press sufficiently redistributed the lead compounds to enable the maximum ballistic effect to be obtained. Evaluation of Pilot Lot No. 334B indicated that it exhibited mesa-type, low temperature coefficient ballistics similar to standard T19 Propellant. The difference in the ballistic results obtained between Pilot Lot No. 334A and Pilot Lot No. 334B, both of which were manufactured from the same lot of nitrocellulose, indicates the limitations of the small-scale solventless equipment available at this Arsenal. Although the two lots were manufactured by the same procedure, the former did not possess an adequate distribution of lead salts as evidenced by the results of reworking this lot of propellant - Pilot Lot No. 334A1. Such a discrepancy is not unusual, as previous work has indicated that the solventless processing of large-scale lots invariably results in a superior product when compared to the propellant produced from the small-scale solventless equipment. The major drawback to date in the 30-pound scale facilities has been the lack of an adequate slurry tank to properly disperse the propellant ingredients. Further work, which will consist of conducting extensive static firing tests on Pilot Lot Nos. 334B and 335A to corroborate the strand ballistic results, will be reported upon completion of these tests.

EXPERIMENTAL PROCEDURE:

13. Thirty-pound batches of Pilot Lot Nos. 144-149 were manufactured by the slurry process to the even-speed sheet stage in accordance with the procedure described in Picatinny Arsenal Technical Report No. 1781. From the even-speed sheets, four-inch diameter discs were punched and these discs were subsequently extruded in a four-inch solventless extrusion press as a solid rod one inch in diameter.

14. Two-hundred-and-forty-pound batches of Pilot Lot Nos. 276B, 334, and 335 were manufactured by blending eight thirty-pound batches after drying the paste to a moisture content of 8 to 12 percent and were extruded as grains 5 inches OD by 1 inch ID by 10 inches long for accelerated storage and shock-cycle tests. Ninety-pound batches of Pilot Lot Nos. 334A, 334B, and 335A were manufactured by blending three thirty-pound batches after drying the paste to a moisture content of 8 to 12 percent and were

extruded as grains 1.7 inches OD by 0.6 inches ID by 6 inches long for ballistic evaluation in the 2-inch test motor. Pilot Lot No. 334A1 was manufactured from Pilot Lot No. 334A by cutting the extruded grains into wafers, rolling the wafers into even-speed sheets, punching four-inch diameter discs from the sheets, and extruding in a four-inch solventless extrusion press as a 1-inch solid rod from which burning-rate strands were prepared. Large-scale lots of Pilot Lot No. 276A (750 lb) and Slurry No. 614 (1952) (1700 lb) were manufactured by the slurry process and extruded into grains in standard production-type solventless equipment. For both the small-scale and the large-scale lots, the triacetin, which is a water-soluble, non-explosive plasticizer, was incorporated directly into the slurry tank. The procedure used is reported in Picatinny Arsenal Technical Report No. 1781.

15. The 90°C. vacuum stability test and the 120°C. heat test values were determined according to the method described in Picatinny Arsenal Technical Report No. 1401, Revision 1. The 110°C. Taliani test was conducted in accordance with NAVORD OS 6478.

16. The accelerated storage test was conducted at 170°F. by storing two grains, 5 inches OD by 1 inch ID by 10 inches long, for each composition in converted 105 mm cartridge storage containers and determining the days to cracking by daily visual examination.

17. The cyclic test was conducted on two grains, 5 inches OD by 1 inch ID by 10 inches long, by shock-cycling between -75°F. and 170°F., with one cycle consisting of 24-hour storage at each temperature. One grain of each composition was started at -75°F. and the other grain was started at +170°F., with the grains being stored naked. Visual inspection for cracking was conducted at the end of each half-cycle when the grains were transferred from one extreme temperature to the other.

18. The procedure used in determining the heat of explosion is described in Picatinny Arsenal Chemical Laboratory Report No. 134476.

19. The procedure used in determining the strand burning-rate data is described in Picatinny Arsenal Technical Report No. 1820.

20. The procedure used to determine the compression data is

in accordance with the "Method for Determining the Compressive Properties of Solid Rocket Propellants" as recommended by the Joint Army-Navy Panel on Physical Properties of Solid Propellants.

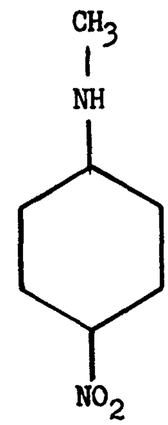
21. The tensile test specimen consisted of a cylindrical gage section 0.5 inch in diameter by 2.25 inches long and cylindrical end sections 0.6 inch in diameter with a 3-inch radius at the junction between the gage and end sections. The over-all length for the specimen was 6 inches. The speed of testing was 0.1 inch per minute per inch of specimen gage length.

INCLOSURES:

1-3. Tables 1-3
4-18. Figs 1-15
19-25. Photographs M-42406/3, M-42406/5, M-42406/1, M-42931, M-42933, M-42930, M-42932

Table 1

Properties of 4-Nitro-N-Methylaniline Received from Eastman Kodak Co.

Composition	4-Nitro-N-Methylaniline
Formula	

Analysis

Color	Yellow
Form	Impalpable powder
Purity	100.15
Melting point, °C	151
Moisture, %	0.05
Acetone insoluble matter, %	0.02
Ash, %	0.04
Acidity, mg KOH/g of sample	0.05
pH of water extract	5.0

(Determined at Picatinny Arsenal as described in General Laboratory Report No. 53-HI-2892)

TABLE 2

Stability, Ballistic, Physical, and Processing Characteristics of Pilot Lot Nos. 144-149

Pilot Lot No.	144 (T16 Propellant) Nominal	144 Analysis	145 Nominal	145 Analysis	146 Nominal	146 Analysis	147 Nominal	147 Analysis	148 Nominal	148 Analysis	149 Nominal	149 Analysis
A. Composition, %												
Nitrocellulose, 12.2%N	55.5	53.26	55.5	54.37	55.5	56.1	55.5	56.1	55.5	55.98	55.5	55.5
Nitroglycerin	27.5	28.17	27.5	28.13	27.5	28.1	27.5	27.1	27.5	27.49	27.5	27.3
Triacetin	13.0	14.54	13.0	13.13	13.0	11.7	13.0	13.1	13.0	12.55	13.0	13.4
Ethyl Centralite	2.0	2.15	1.0	0.92	1.0	1.0	--	--	--	--	--	--
2-Nitrodiphenylamine	--	--	1.0	1.17	--	--	1.0	0.9	2.0	2.12	--	--
4-Nitro - N - Methylaniline*	--	--	--	--	1.0	1.0	1.0	0.9	--	--	2.0	1.8
Lead Stearate	2.0	1.88	2.0	2.28	2.0	2.1	2.0	1.9	2.0	1.86	2.0	2.0
Carbon Black (added)	0.03	0.08	0.03	0.06	0.03	0.07	0.03	0.07	0.03	0.07	0.03	0.09

*Eastman Kodak Co.

B. Stability Characteristics	144	145	146	147	148	149
1. 120°C Heat Test						
Salmon Pink, min	85	80	130	140	95	185
Red Fumes, min	90	85	135	145	100	190
Explosion, min	300+	300+	300+	300+	300+	300+
2. 90°C Vacuum Stability Test						
Ml. gas after 40 hours	2.23	2.18	0.56	0.42	1.20	0.39
3. 110°C Taliani Test						
Slope at 100 mm	0.85	0.89	0.68	0.55	0.57	0.36
Minutes to 100 mm	180	114	252	286	222	298
Slope at 100 min	1.05	0.58	0.18	0.35	0.77	0.20
4. 65.5°C Surveillance Test						
No. of days in progress as of December 15, 1953 with no end point.	689	686	686	696	696	696

C. Ballistic Characteristics	144	145	146	147	148	149
1. Heat of Explosion, cal/gm						
Calculated (Nominal)	734	744	750	758	752	765
Calculated (Analysis)	703	736	779	757	762	755
Experimental	761	771	763	773	766	767

2. Strand Burning-Rate Data	144 (see Fig 1) 70°F	144 160°F	145 (see Fig 2) 70°F	145 160°F	146 (see Fig 3) 70°F	146 160°F	147 (see Fig 4) 70°F	147 160°F	148 (see Fig 5) 70°F	148 160°F	149 (see Fig 6) 70°F	149 160°F
(a) Burning Rate, ips												
1000 psi	0.32	0.33	0.33	0.39	0.27	0.27	0.33	0.36	0.33	0.37	0.31	0.32
1500 psi	0.22	0.29	0.27	0.31	0.22	0.28	0.26	0.34	0.30	0.35	0.23	0.31
2000 psi	0.27	0.35	0.29	0.36	0.28	0.35	0.30	0.38	0.31	0.41	0.27	0.36

(b) Pressure Exponent, N, at 70°F	144 Press Int	144 N	145 Press Int	145 N	146 Press Int	146 N	147 Press Int	147 N	148 Press Int	148 N	149 Press Int	149 N
	600-800	0.50	600-800	0.93	600-800	0.30	600-800	0.50	600-800	0.07	600-800	0.77
	800-1190	0.09	800-1240	0.07	800-1000	-0.23	800-1000	0.12	800-1000	1.23	800-1000	-0.21
	1190-1400	-1.25	1240-1600	-1.20	1000-1240	-1.57	1000-1220	-1.50	1000-1700	-0.30	1000-1200	-2.30
	1400-2600	0.72	1600-2600	0.62	1240-2600	0.72	1220-2600	0.47	1700-2600	0.60	1200-2000	0.61
											2000-2600	0.83

(c) Temperature Coefficient (TC) of Pressure at Constant P/r from 70 to 160°F, %/°F	144 Press at 70°F	144 P/r	144 TC	145 Press at 70°F	145 P/r	145 TC	146 Press at 70°F	146 P/r	146 TC	147 Press at 70°F	147 P/r	147 TC	148 Press at 70°F	148 P/r	148 TC	149 Press at 70°F	149 P/r	149 TC
	800	2530	0.07	800	2380	0.13	800	2820	0	800	2560	0.17	800	3080	0.40	800	2470	0.08
	1000	3080	0	1000	2990	0.10	1000	3700	0	1000	3080	0.06	1000	2980	0.13	1000	3230	0
	1200	4350	0	1200	3510	-0.03	1100	4710	0.08	1100	3840	0.12	1200	3780	0.11	1100	4260	0.10
	1300	5550	0.39	1400	4650	0	1200	5890	0.68	1200	4800	0.38	1400	4650	0.28	1150	5000	0.38
				1500	5550	0.32												

D. Physical Characteristics	144			145			146			147			148			149		
1. Compressive Properties																		
Temperature, °F	-65	77	160	-65	77	160	-65	77	160	-65	77	160	-65	77	160	-65	77	160
Stress at Rupture, psi	32600	--	--	30600	--	--	26100	--	--	25400	--	--	27900	--	--	23600	--	--
% Compression at Rupture	3.7	--	--	3.2	--	--	3.8	--	--	3.6	--	--	3.5	--	--	4.1	--	--
Stress at 60% Compression, psi	--	2600	199	--	2360	281	--	2830	315	--	2510	276	--	2650	287	--	2840	258
Work to Produce Rupture or 60% Compression, ft-lb/cu.in.	59.8	61.7	5.1	47.2	56.1	8.6	41.0	67.0	7.1	42.6	60.5	5.8	30.3	64.9	7.9	49.3	68.6	5.2

2. Tensile Properties	144		145		146		147		148		149	
Temperature, °F	77	160	77	160	77	160	77	160	77	160	77	160
Stress at Separation, psi	440	73.6	446	92.5	391	74.3	486	97.5	466	98.9	468	79.1
% Elongation at Separation	20.9	18.7	17.9	18.3	15.6	16.9	17.0	14.7	15.4	12.2	19.1	19.9
Work to Produce Separation, ft-lb/cu.in.	5.7	0.7	5.0	0.8	3.6	0.6	5.2	0.7	5.6	0.6	5.8	0.9

E. Processing Characteristics

Small-scale (30-lb) batches of all the above compositions processed satisfactorily to the even-speed sheet stage and were extruded with no difficulty. No appreciable difference was detected in the processing characteristics or in the texture and appearance of the final sheets and grains for the above compositions except for slight variations in color. Basically all of the compositions were black. However, the introduction of 2-nitro diphenylamine to the T16 Matrix resulted in an orange tint while the addition of 4-nitro - N - methylaniline caused a green shade.

CONFIDENTIAL

TABLE 2

Stability, Accelerated Storage, Cyclic, Ballistic, and Processing Characteristics of Pilot Lot Nos 334, 334A, 334A1, 334B, 335, 335A, T16 and T19 Propellants

Pilot Lot No.	334		334A	334A1	334B		T19 (Pilot Lot No. 270B)	T19 (Pilot Lot No 276A)		335		335A		T16 (Slurry No. 614-1952)	
A. Composition, %	Nominal	Analysis	Nominal	Nominal	Nominal	Analysis	Nominal	Nominal	Analysis	Nominal	Analysis	Nominal	Analysis	Nominal	Analysis
Nitrocellulose, 12.2%N	53.0	53.14	53.0	53.0	53.0	52.49	53.0	53.0	53.66	55.5	55.03	55.5	55.13	55.5	55.09
Nitroglycerin	31.0	30.61	31.0	31.0	31.0	30.77	31.0	31.0	30.98	27.5	26.72	27.5	27.57	27.5	27.15
Triacetin	11.0	12.09	11.0	11.0	11.0	12.06	11.0	11.0	10.96	13.0	14.38	13.0	13.44	13.0	13.32
Ethyl Centralite	1.0	0.78	1.0	1.0	1.0	1.05	2.0	2.0	2.23	1.0	1.04	1.0	1.06	2.0	2.28
4-Nitro-N-Methylaniline*	1.0	1.29	1.0	1.0	1.0	1.09	—	--	—	1.0	0.88	1.0	0.92	—	--
Lead Salicylate	2.5	1.43	2.5	2.5	2.5	1.09	2.5	2.5	1.26	--	--	—	—	—	—
Lead Stearate	0.5	0.50	0.5	0.5	0.5	0.45	0.5	0.5	0.62	2.0	1.95	2.0	1.96	2.0	2.16
Carbon Black (added)	0.03	0.07	0.03	0.03	0.03	0.04	0.03	0.03	0.07	0.03	0.04	0.03	0.11	0.03	0.08
Lead**	--	0.16	—	—	—	0.46	--	—	0.29	--	—	—	--	—	--

*Eastman Kodak Co.

**Balance of lead as determined from difference of total lead and lead present as lead salicylate and lead stearate

B. Stability Characteristics	334	334A	334A1	334B	T19 (270B)	T19 (276A)	335	335A	T16
1. 120°C Heat Test									
Salmon Pink, min	115	125	--	120	75	85	130	140	80
Red Fumes, min	125	135	-	125	85	96	145	150	95
Explosion, min	300+	300+	—	300+	300+	300+	300+	300+	300+
2. 90°C Vacuum Stability Test									
Ml. gas after 40 hours	0.83	0.74	—	0.42	3.36	1.33	0.56	0.39	1.84
3. 110°C Taliani Test									
Slope at 100 mm	0.77	0.70	--	0.81	0.95	0.99	0.63	0.63	0.81
Minutes to 100 mm	264	270	—	180	118	128	260	296	176
Slope at 100 min	.25	0.25	--	0.15	0.87	1.03	0.28	0.23	0.97
4. 65.5°C Surveillance Test									
No. of days in progress as of December 15, 1953 with no end-point	477	264	--	261	477	394	461	264	491*
5. Accelerated Storage Test (5" OD x 1" ID x 10" long) Days to Cracking at 170°F	11 (Photo N-42403/3)	—	—	—	4 (Photo N-42406/1)	—	18 (Photo N-42406/5)	—	16 (No Photo)
6. Cyclic Test (5" OD x 1" ID x 10" long) No. of cycles to cracking from -75° to 170°F (One cycle consists of 24 hrs exposure at each temperature)	Initial Temp -75°F: 8½; Initial Temp 170°F: 7½ (Photo N-42931)	--	--	—	Initial Temp -75°F: 3½; Initial Temp 170°F: 3½ (Photo N-42930)	—	Initial Temp -75°F: 11½; Initial Temp 170°F: 12½ (Photo N-42933)	--	Initial Temp -75°F: 7½; Initial Temp 170°F: 10 (Photo N-42932)

*The earliest lot of T16 Propellant (Pilot Lot No. 53) manufactured at this arsenal is still in progress after 1185 days with no end-point

C. Ballistic Characteristics

1. Heat of Explosion, cal/gm	334	334A	334A1	334B	T19 (270B)	T19 (276A)	335	335A	T16
Calculated (Nominal)	825	825	825	825	812	812	750	750	734
Calculated (Analysis)	815	—	--	805	—	823	741	713	708
Experimental	792	798	798	830	791	846	742	761	758

2. Strand Burning-Rate Data

(a) Burning-Rate, ips

Pilot Lot	See	1000 psi -40°F	1000 psi 70°F	1000 psi 160°F	1500 psi -40°F	1500 psi 70°F	1500 psi 160°F	2000 psi -40°F	2000 psi 70°F	2000 psi 160°F
334	Fig 7	0.33	0.40	0.49	0.35	0.44	0.47	0.26	0.36	0.46
334A	Fig 8	0.38	0.48	0.50	0.42	0.53	0.56	0.35	0.45	0.51
334A1	Fig 9	0.40	0.53	0.53	0.46	0.58	0.57	0.42	0.47	0.52
334B	Fig 10	0.44	0.48	0.48	0.49	0.52	0.51	0.32	0.39	0.50
T19 (270B)	Fig 11	0.34	0.43	0.49	0.31	0.46	0.52	0.27	0.35	0.48
T19 (276A)	Fig 12	0.47	0.48	0.44	0.52	0.54	0.51	0.44	0.39	0.51
335	Fig 13	0.21	0.30	0.44	0.16	0.20	0.29	0.20	0.27	0.39
335A	Fig 14	0.24	0.34	0.35	0.22	0.27	0.29	0.21	0.28	0.40
T16	Fig 15	0.24	0.30	0.36	0.17	0.21	0.31	0.21	0.29	0.39

(b) Pressure Exponent, n, at 70°F

Pilot Lot	Press Int	n	Press Int	n	Press Int	n	Press Int	n
334	600-1100	0.51	1100-1470	0.21	1470-1900	-1.10	1900-2600	0.50
334A	600-1140	0.68	1140-1700	0	1700-2250	-0.99	2250-2600	0.44
334A1	600-1050	1.08	1050-1600	0.13	1600-2400	-0.92	2400-2600	0.61
334B	600-1200	0.63	1200-1600	0.20	1600-2000	-1.21	2000-2600	1.18
T19 (270B)	600-1200	0.33	1200-1550	0	1550-1880	-1.80	1880-2600	0.62
T19 (276A)	600-1300	0.62	1300-1600	-0.28	1600-2000	-1.30	2000-2600	0.56
335	800-1200	0	1200-1500	-1.90	1500-2600	0.93		
335A	600-1000	0.51	1000-1270	0	1270-1570	-1.57	1570-2600	0.49
T16	600-800	0.69	800-1000	0	1000-1430	-1.18	1430-2000	1.14

(c) Temperature Coefficient (TC of Pressure at Constant P/r from -40° to 160°F, %/°F)

Pilot Lot	Press at 70°F	P/r	TC
334	1000	2500	0.33
	1200	3820	0.20
	1400	3140	0.18
	1600	3920	0.13
	1700	4410	0.14
334A	1200	2270	0.29
	1400	2680	0.19
	1600	3030	0.15
	1800	3570	0.12
334A1	1400	2500	0.17
	1600	2810	0.15
	1800	3450	0.06
	2000	4280	0.08
334B	1200	2220	0.11
	1400	2700	0.04
	1600	3120	0.03
	1800	4160	0.09
T19 (270B)	1200	2630	0.27
	1400	3030	0.18
	1600	3640	0.15
	1650	4000	0.14
T19 (276A)	1200	2250	0.09
	1400	2560	0.04
	1600	3080	0.02
	1700	3450	0.03
	1800	4000	0.07
335	1150	3800	0.25
	1200	4000	0.23
	1250	4630	0.20
	1300	5080	0.17
335A	1000	2860	0.25
	1200	3450	0.23
	1400	4650	0.11
	1500	5550	0.24
T16	1000	3280	0.26
	1200	3890	0.16
	1250	4550	0.11
	1300	5050	0.23

D. Processing Characteristics

Two-hundred-and-forty-pound batches of Pilot Lot Nos. 270B, 334, and 335 were manufactured and extruded as grains 5" OD by 1" ID by 10" long for accelerated storage and cyclic tests. Ninety-pound batches of Pilot Lot Nos. 334A, 334B, and 335A were manufactured and extruded as grains 1.7" OD by .6" I. D by 6" long for ballistic evaluation in the 2" test motor. Pilot Lot No. 334A1 was manufactured from Pilot Lot No. 334A by cutting the extruded grains into wafers, rolling the wafers into even-speed sheets, punching 4" diameter discs from the sheets, and extruding in a 4" solventless extrusion press as a 1" solid rod, from which burning-rate strands were prepared. Pilot Lot No 276A and Slurry No 614 represent large-scale lots (750 lb and 1700 lb, respectively) of T19 and T16 Propellant. All the above lots of T16 and T19 Propellant modified by the incorporation of 1% 4-nitro-N-methylaniline plus 1% ethyl centralite processed satisfactorily to the even-speed sheet stage and were extruded with no difficulty. No appreciable difference was detected in the processing characteristics or in the texture and appearance of the final sheets and grains for the different compositions. In all cases the incorporation of 4-nitro-N-methylaniline resulted in a greenish tint to the normally black color of T16 and T19 Propellants.

CONFIDENTIAL

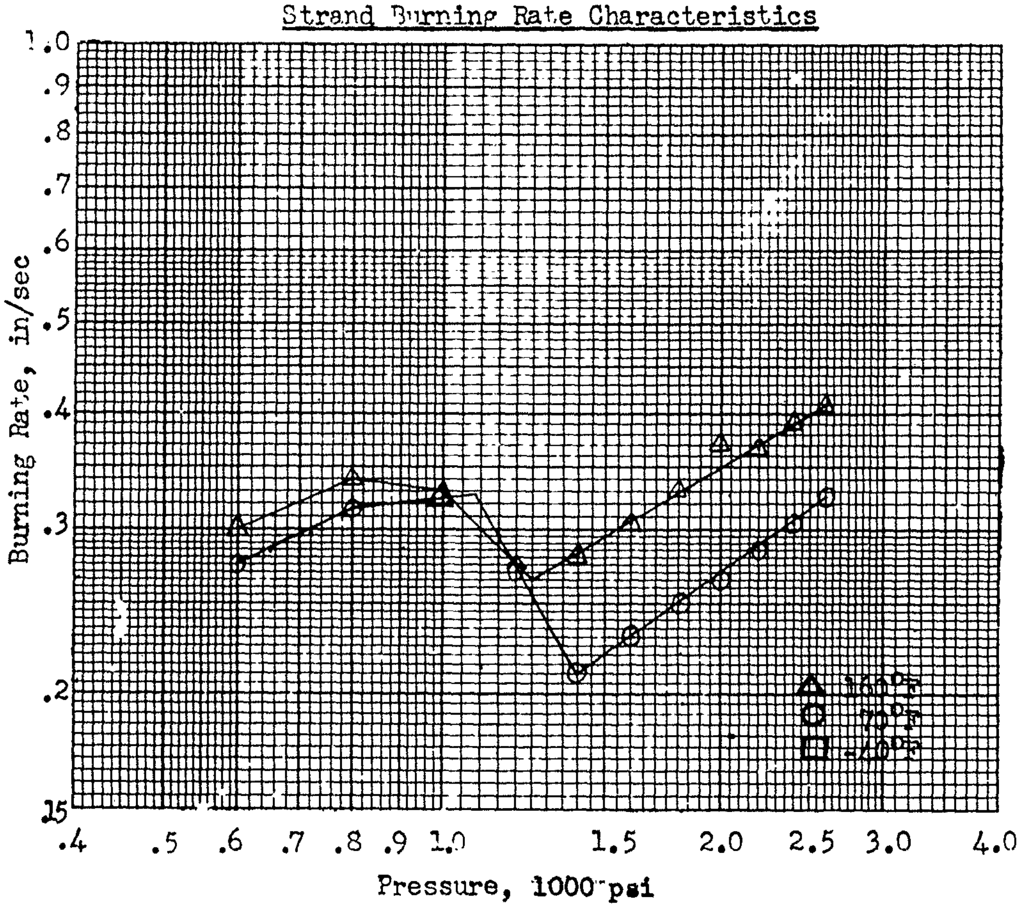
Propellant Data Sheet for Pilot Lot No. 144

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	53.26
Nitroglycerin	27.5	28.17
Triacetin	13.0	14.54
Ethyl Centralite	2.0	2.15
Lead Stearate	2.0	1.88
Carbon Black (added)	0.03	0.08

Thermodynamic Properties	
Heat of Explosion, cal/gm	
Calc (Nom)	734
Expt	761
Calc (Anal)	703

*Hercules Lot No. 9251Y

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-800	0.50
800-1190	0.09
1190-1400	-1.25
1400-2600	0.72

Temp Coeff of Pressure at Constant P/r from 70°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
800	2530	0.07
1000	3080	0
1200	4350	0
1300	5550	0.39

Figure 1

CONFIDENTIAL

Propellant Data Sheet for Pilot Lot No. 145

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	54.37
Nitroglycerin	27.5	28.13
Triacetin	13.0	13.13
Ethyl Centralite	1.0	0.92
2-Nitrodiphenylamine	1.0	1.17
Lead Stearate	2.0	2.28
Carbon Black (added)	0.03	0.06

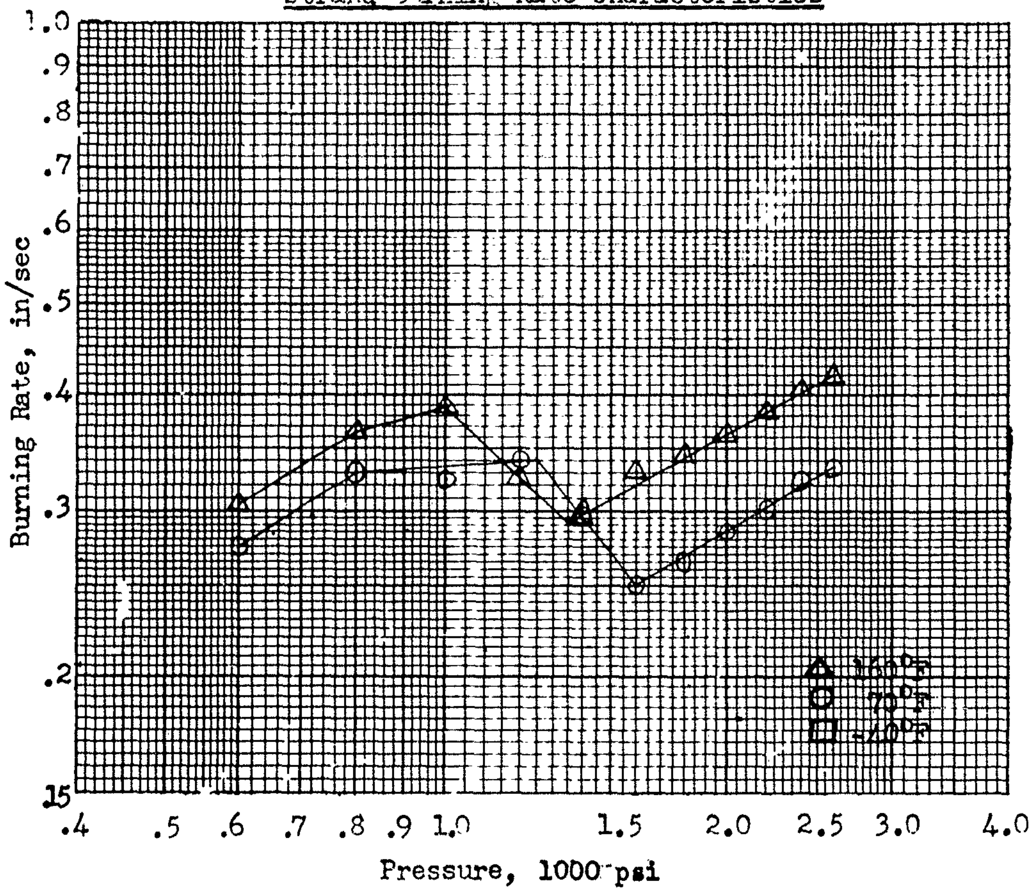
Thermodynamic Properties

Heat of Explosion, cal/gm

Calc	(Nom)	744
Expt		771
Calc	(Anal)	736

*Hercules Lot No. 9251Y

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-800	0.93
800-1240	0.07
1240-1600	-1.20
1600-2600	0.62

Temp Coeff of Pressure at Constant P/r from -20°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
800	2380	0.13
1000	2990	0.10
1200	3510	-0.03
1400	4650	0
1500	5550	0.32

CONFIDENTIAL

Figure 2

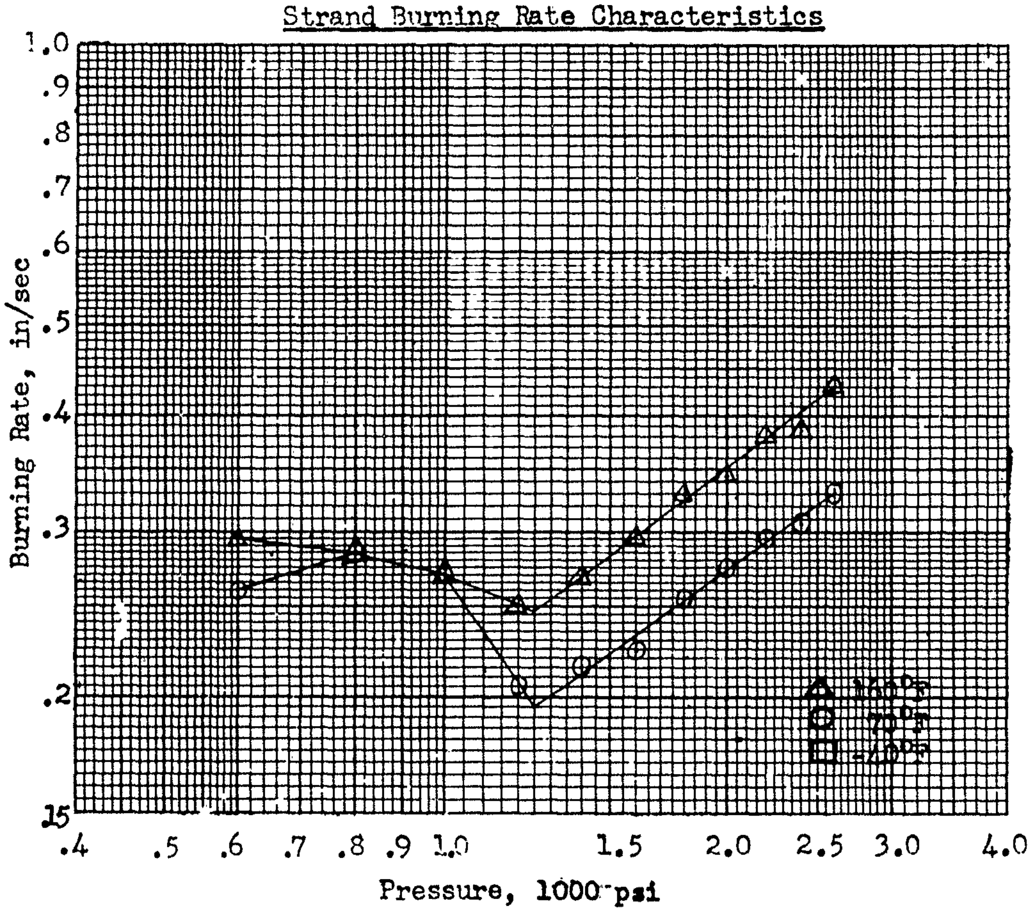
Propellant Data Sheet for Pilot Lot No. 146

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	56.1
Nitroglycerin	27.5	28.1
Triacetin	13.0	11.7
Ethyl Centralite	1.0	1.0
4-Nitro-N-Methylaniline	1.0	1.0
Lead Stearate	2.0	2.1
Carbon Black (added)	0.03	0.07

Thermodynamic Properties	
Heat of Explosion, cal/gm	
Calc (Nom)	750
Expt	763
Calc (Anal)	779

*Hercules Lot No. 9251Y

Strand Burning Rate Characteristics



Pressure Exponent at 70°F	
Press Range, psi	Slope (n)
600-800	0.30
800-1000	-0.23
1000-1240	-1.57
1240-2600	0.72

Temp Coeff of Pressure at Constant P/r from -70°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
800	2820	0
1000	3700	0
1100	4710	0.08
1200	5890	0.68

Figure 3

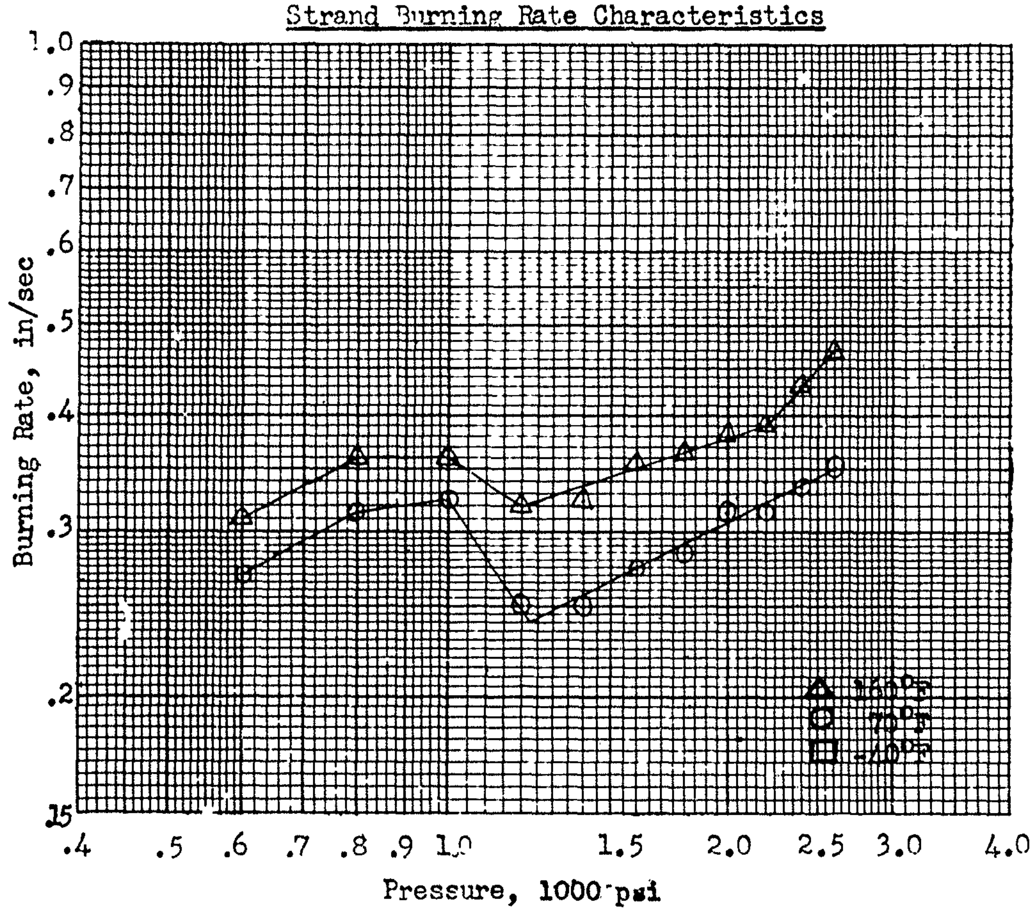
Propellant Data Sheet for Pilot Lot No. 147

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	56.1
Nitroglycerin	27.5	27.1
Triacetin	13.0	13.1
2-Nitrodiphenylamine	1.0	0.9
4-Nitro-N-Methylaniline	1.0	0.9
Lead Stearate	2.0	1.9
Carbon Black (added)	0.03	0.07

Thermodynamic Properties	
Heat of Explosion, cal/gm	
Calc (Nom)	758
Expt	773
Calc (Anal)	757

*Hercules Lot No. 9249Y

Strand Burning Rate Characteristics



Pressure Exponent at 70°F	
Press Range, psi	Slope (n)
600-800	0.50
800-1000	0.12
1000-1220	-1.50
1220-2600	0.47

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
800	2560	0.17
1000	3080	0.06
1100	3840	0.12
1200	4800	0.38

Figure 4

CONFIDENTIAL

Propellant Data Sheet for Pilot Lot No. 148

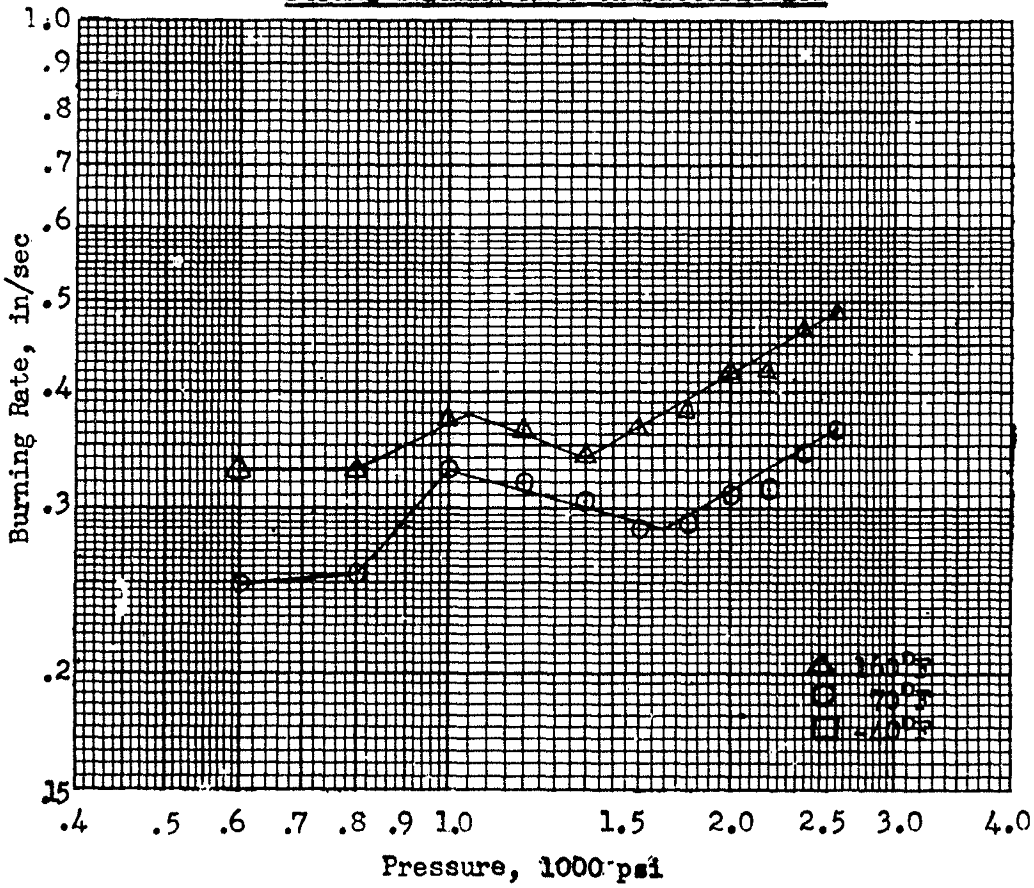
Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	55.98
Nitroglycerin	27.5	27.49
Triacetin	13.0	12.55
2-Nitrodiphenylamine	2.0	2.12
Lead Stearate	2.0	1.86
Carbon Black (added)	0.03	0.07

*Hercules Lot No. 9249Y

Thermodynamic Properties

Heat of Explosion, cal/gm	
Calc (Nom)	752
Expt	766
Calc (Anal)	762

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-800	0.07
800-1000	1.23
1000-1700	-0.30
1700-2600	0.60

Temp Coeff of Pressure at Constant P/r from -70°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
800	3080	0.40
1000	2980	0.13
1200	3780	0.11
1400	4650	0.28

CONFIDENTIAL

Figure 5

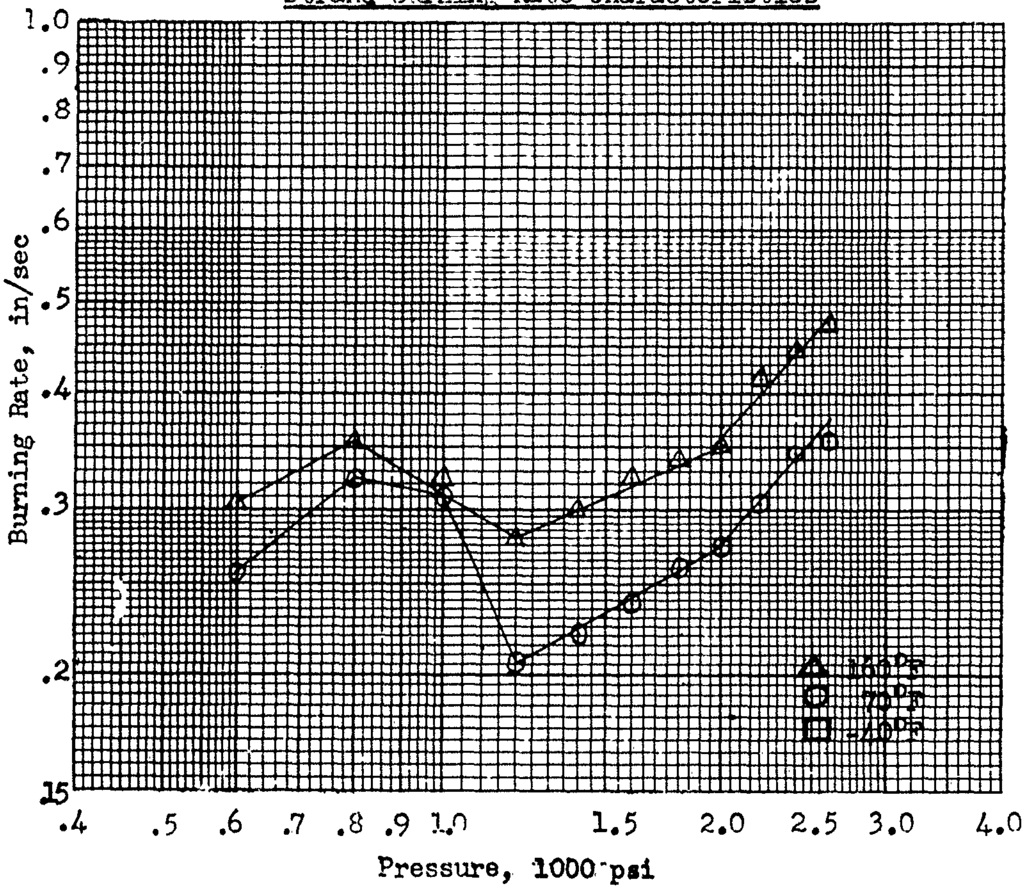
Propellant Data Sheet for Pilot Lot No. 149

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	55.5
Nitroglycerin	27.5	27.3
Triacetin	13.0	13.4
4-Nitro-N-Methylaniline	2.0	1.8
Lead Stearate	2.0	2.0
Carbon Black (added)	0.03	0.09

Thermodynamic Properties		
Heat of Explosion, cal/gm		
Calc	(Nom)	765
Expt		767
Calc	(Anal)	755

*Hercules Lot No. 9249Y

Strand Burning Rate Characteristics



Pressure Exponent at 70°F	
Press Range, psi	Slope (n)
600-800	0.77
800-1000	-0.21
1000-1200	-2.30
1200-2000	0.61
2000-2600	0.83

Temp Coeff of Pressure at Constant P/r from -70°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
800	2470	0.08
1000	3230	0
1100	4260	0.10
1150	5000	0.38

Figure 6

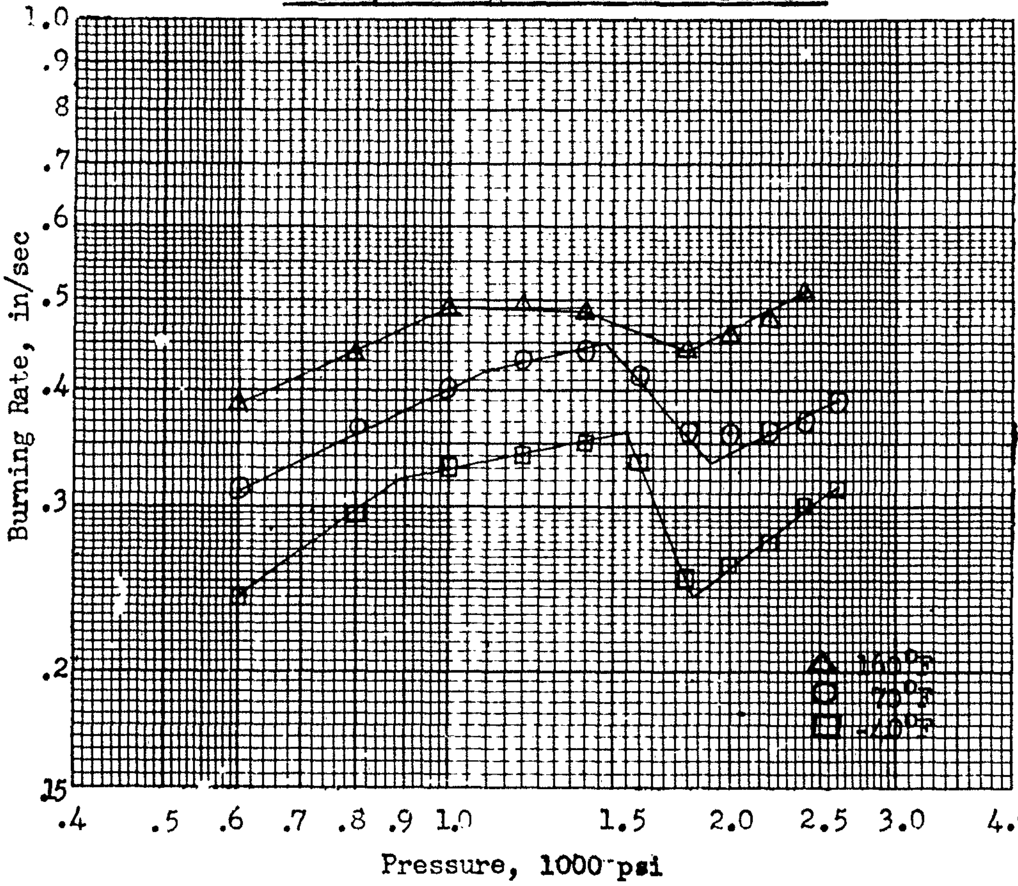
Propellant Data Sheet for Pilot Lot No. 334

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	53.0	53.14
Nitroglycerin	31.0	30.61
Triacetin	11.0	12.09
Ethyl Centralite	1.0	0.78
4-Nitro-N-Methylaniline	1.0	1.29
Lead Salicylate	2.5	1.43
Lead Stearate	0.5	0.50
Carbon Black (added)	0.03	0.07
Lead**	—	0.16

Thermodynamic Properties

Heat of Explosion, cal/gm	
Calc (Nom)	825
Expt	792
Calc (Anal)	815

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-1100	0.51
1100-1470	0.21
1470-1900	-1.10
1900-2600	0.50

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1000	2500	0.33
1200	3820	0.20
1400	3140	0.18
1600	3920	0.13
1700	4410	0.14

*DuPont Lot No. 3

**Balance of lead as determined from difference of total lead and lead present as lead salicylate and lead stearate.

CONFIDENTI

Figure 7

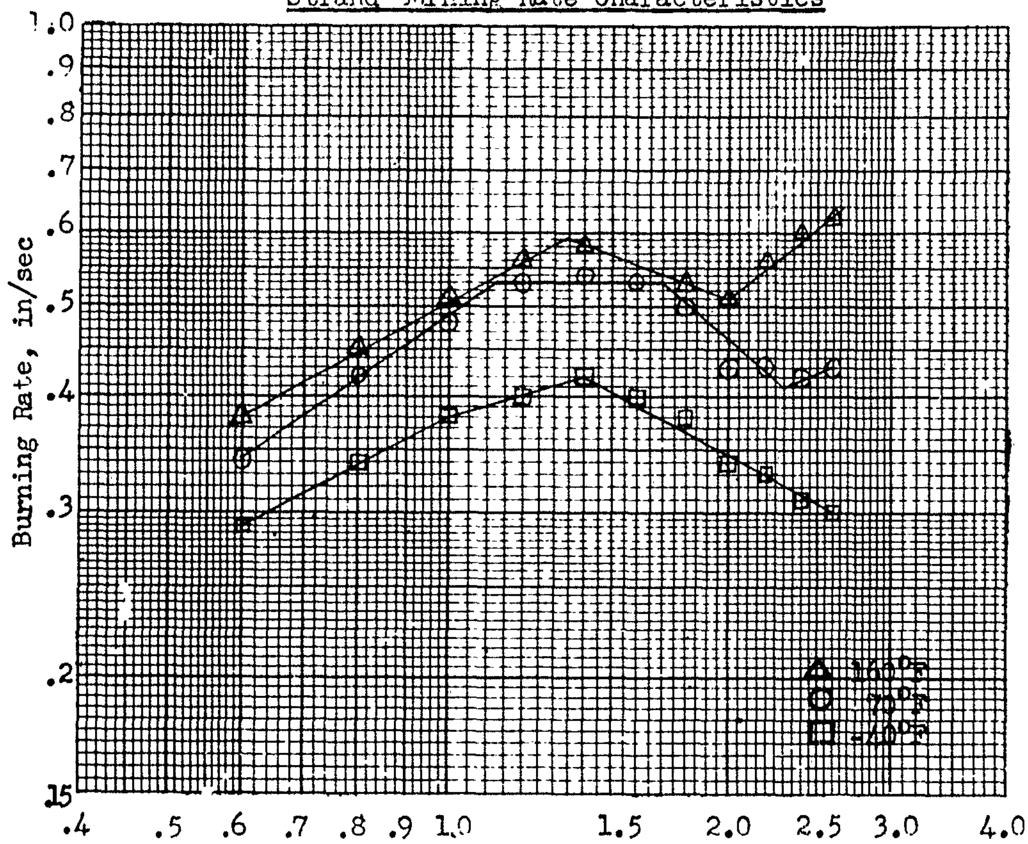
Propellant Data Sheet for Pilot Lot No. 334A

Composition, %	Nominal
Nitrocellulose, 12.2%N*	53.0
Nitroglycerin	31.0
Triacetin	11.0
Ethyl Centralite	1.0
4-Nitro-N-Methylaniline	1.0
Lead Salicylate	2.5
Lead Stearate	0.5
Carbon Black (added)	0.03

*DuPont Lot No. 257

Thermodynamic Properties	
Heat of Explosion, cal/gm	
Calc (Nom)	825
Expt	798

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-1130	0.68
1130-1700	0
1700-2300	-0.85
2300-2600	0.40

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1200	2270	0.29
1400	2680	0.19
1600	3030	0.15
1800	3570	0.12

Figure 8

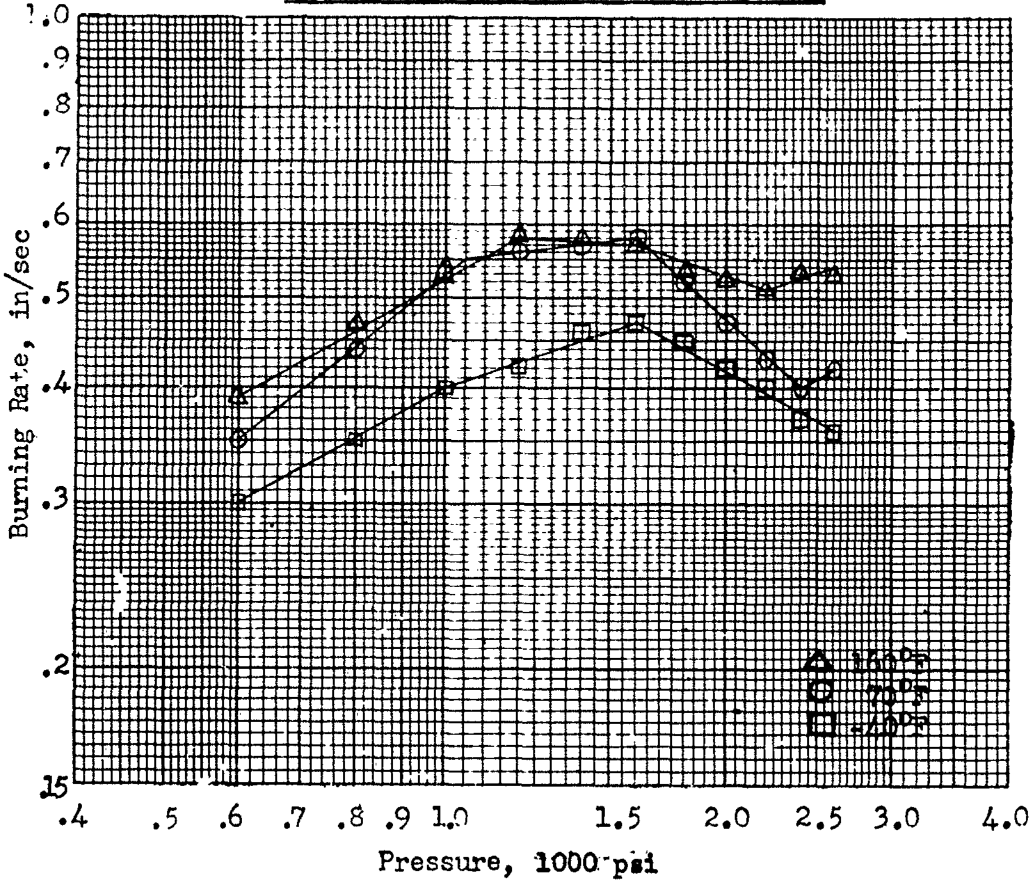
Propellant Data Sheet for Pilot Lot No. 334A-1
(PL 334 Wafered, re-rolled & re-extruded)

Composition, %	Nominal
Nitrocellulose, 12.2%N*	53.0
Nitroglycerin	31.0
Triacetin	11.0
Ethyl Centralite	1.0
4-Nitro-N-Methylaniline	1.0
Lead Salicylate	2.5
Lead Stearate	0.5
Carbon Black (added)	0.03

*DuPont Lot No. 257

Thermodynamic Properties
Heat of Explosion, cal/gm
Calc (Nom)825
Expt

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-1050	1.08
1050-1600	0.13
1600-2400	-0.92
2400-2600	0.61

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1600	2810	0.15
1700	3080	0.10
1800	3450	0.06
2000	4280	0.08
2100	4760	0.10

Figure 9

CONFIDENTIAL

Propellant Data Sheet for Pilot Lot No. 334B

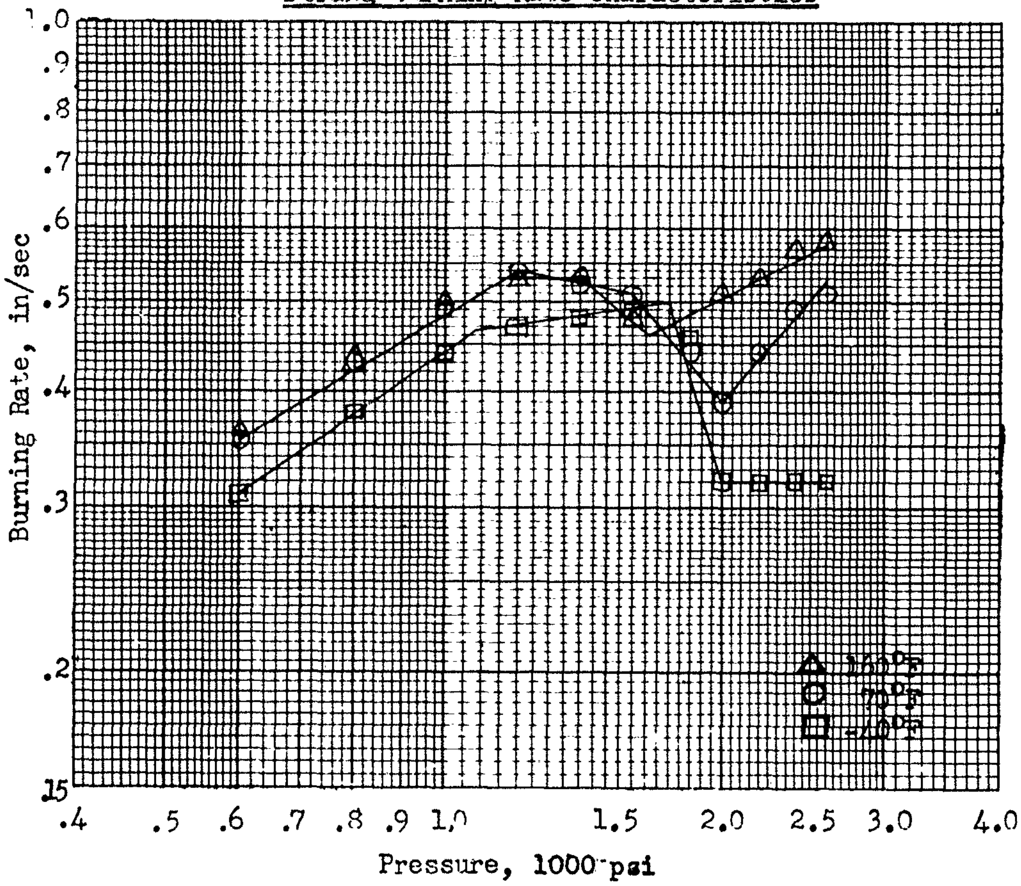
Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	53.0	52.49
Nitroglycerin	31.0	30.77
Triacetin	11.0	12.60
Ethyl Centralite	1.0	1.05
4-Nitro-N-Methylaniline	1.0	1.09
Lead Salicylate	2.5	1.09
Lead Stearate	0.5	0.45
Carbon Black (added)	0.03	0.04
Lead**	--	0.46

Thermodynamic Properties

Heat of Explosion, cal/gm

Calc	(Nom)	825
Expt		830
Calc	(Anal)	805

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
600-1200	0.63
1200-1600	0.20
1600-2000	-1.21
2000-2600	1.18

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1200	2220	0.11
1400	2700	0.04
1600	3120	0.03
1700	3570	0.03
1800	4140	0.09

*DuPont Lot No. 258B

**Balance of lead as determined from difference of total lead and lead present as lead salicylate and lead stearate

CONFIDENTIAL

Figure 10

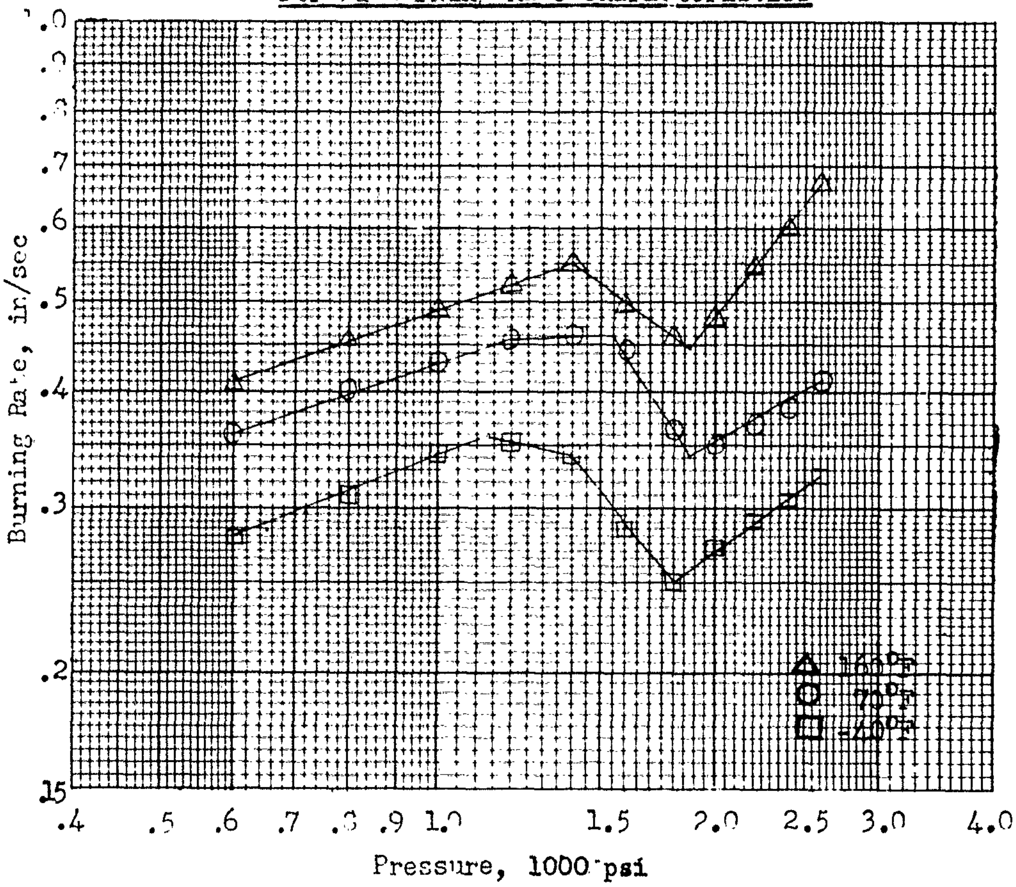
Propellant Data Sheet for Pilot Lot No. 276B (T19 Propellant)

Composition, %	Nominal
Nitrocellulose, 12.2%N*	53.0
Nitroglycerin	31.0
Triacetin	11.0
Ethyl Centralite	2.0
Lead Salicylate	2.5
Lead Stearate	0.5
Carbon Black (added)	0.03

*DuPont Lot No. 3

Thermodynamic Properties		
Heat of Explosion, cal/gm		
Calc	(Nom)	812
Expt		791

Strand Burning Rate Characteristics



Pressure Exponent at 70°F	
Press Range, psi	Slope (n)
600-1200	0.33
1200-1550	0
1550-1880	-1.60
1880-2600	0.62

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1200	2630	0.27
1400	3030	0.18
1600	3640	0.15
1650	4000	0.14

Figure 11

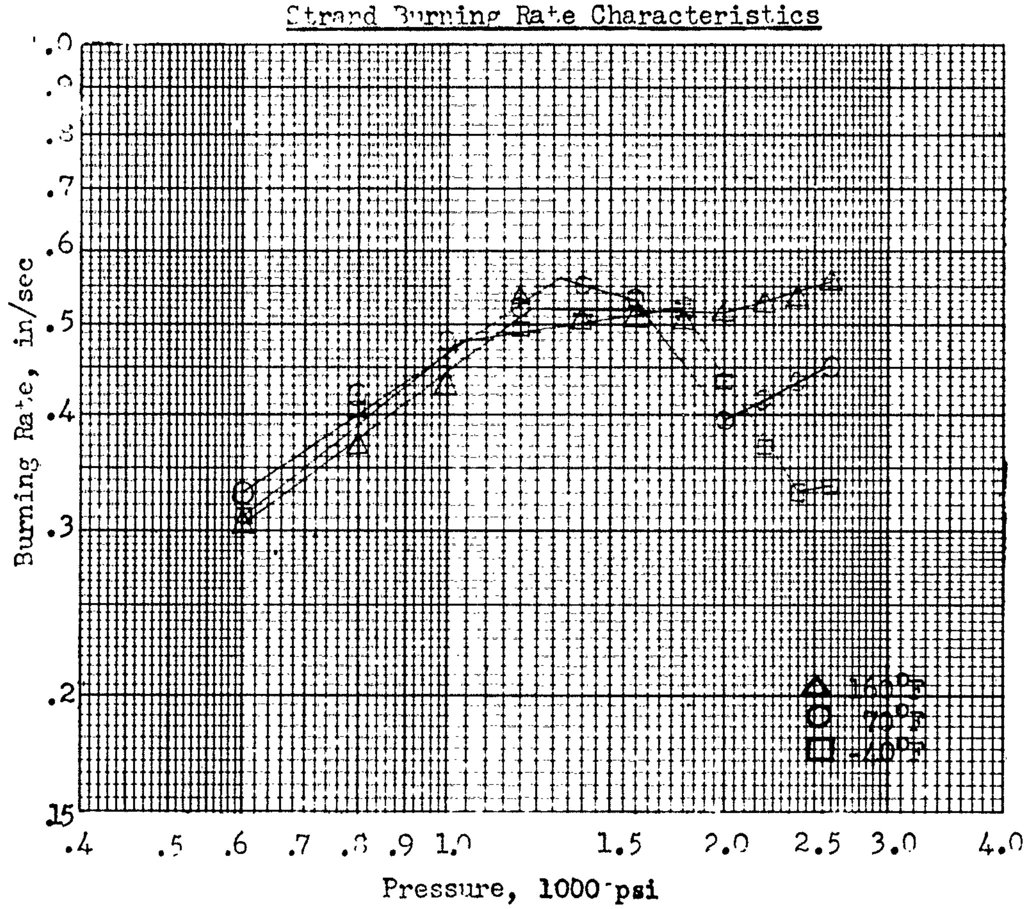
CONFIDENTIAL

Propellant Data Sheet for Pilot Lot No. 276A (T19 Propellant)

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	53.0	53.66
Nitroglycerin	31.0	30.98
Triacetin	11.0	10.96
Ethyl Centralite	2.0	2.23
Lead Salicylate	2.5	1.26
Lead Stearate	0.5	0.62
Carbon Black (added)	0.03	0.07
Lead**	--	0.29

Thermodynamic Properties		
Heat of Explosion, cal/gm		
Calc	(Nom)	812
Expt		826
Calc	(Anal)	823

Strand Burning Rate Characteristics



Pressure Exponent at 70°F	
Press Range, psi	Slope (n)
600-1300	0.62
1300-1600	-0.28
1600-2000	-1.30
2000-2600	0.56

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1200	2250	0.09
1400	2560	0.04
1600	3080	0.02
1700	3450	0.03
1800	4000	0.07

*Hercules Lot No. 9251Y
**Balance of lead as determined from difference of total lead and lead present as lead salicylate and lead stearate.

CONFIDENTIAL

Figure 12

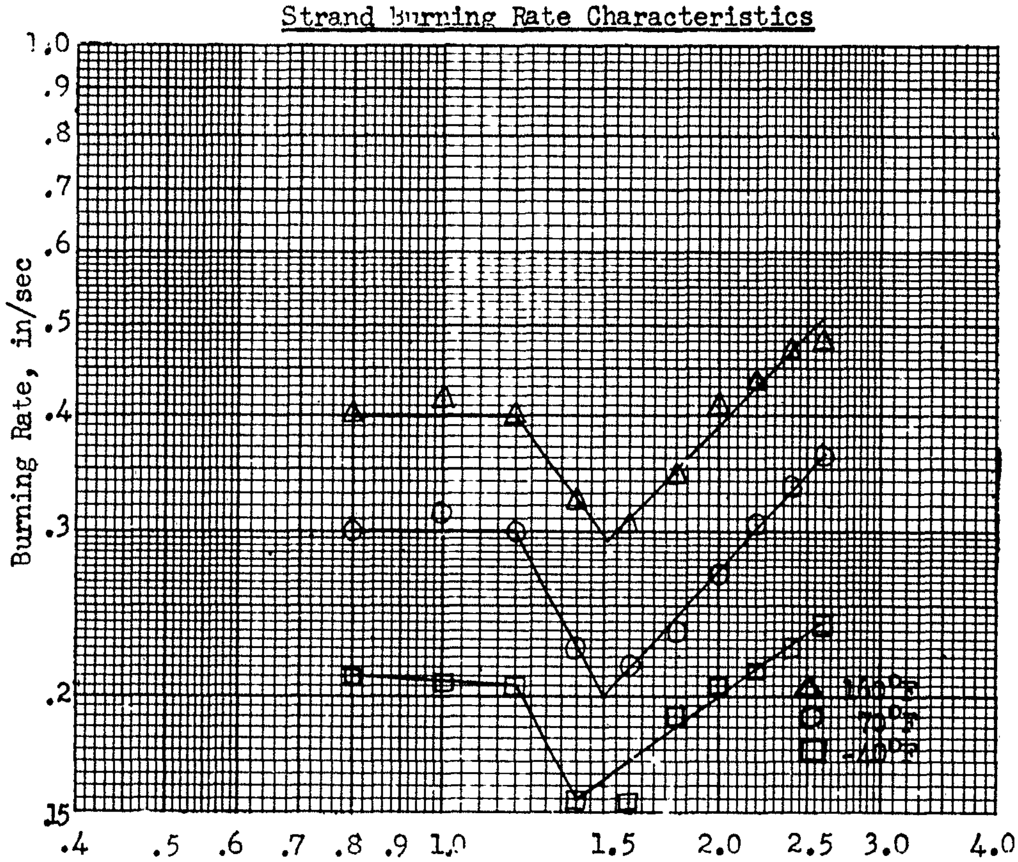
Propellant Data Sheet for Pilot Lot No. 335

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	55.03
Nitroglycerin	27.5	26.72
Triacetin	13.0	14.38
Ethyl Centralite	1.0	1.04
4-Nitro-N-Methylaniline	1.0	0.88
Lead Stearate	2.0	1.95
Carbon Black	0.03	0.02

Thermodynamic Properties		
Heat of Explosion, cal/gm		
Calc	(Nom)	750
Expt		742
Calc	(Anal)	741

*DuPont Lot No. 4

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

Press Range, psi	Slope (n)
800-1200	0
1200-1500	-1.90
1500-2600	0.93

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1150	3800	0.25
1200	4000	0.23
1250	4600	0.20
1300	5080	0.17

Figure 13

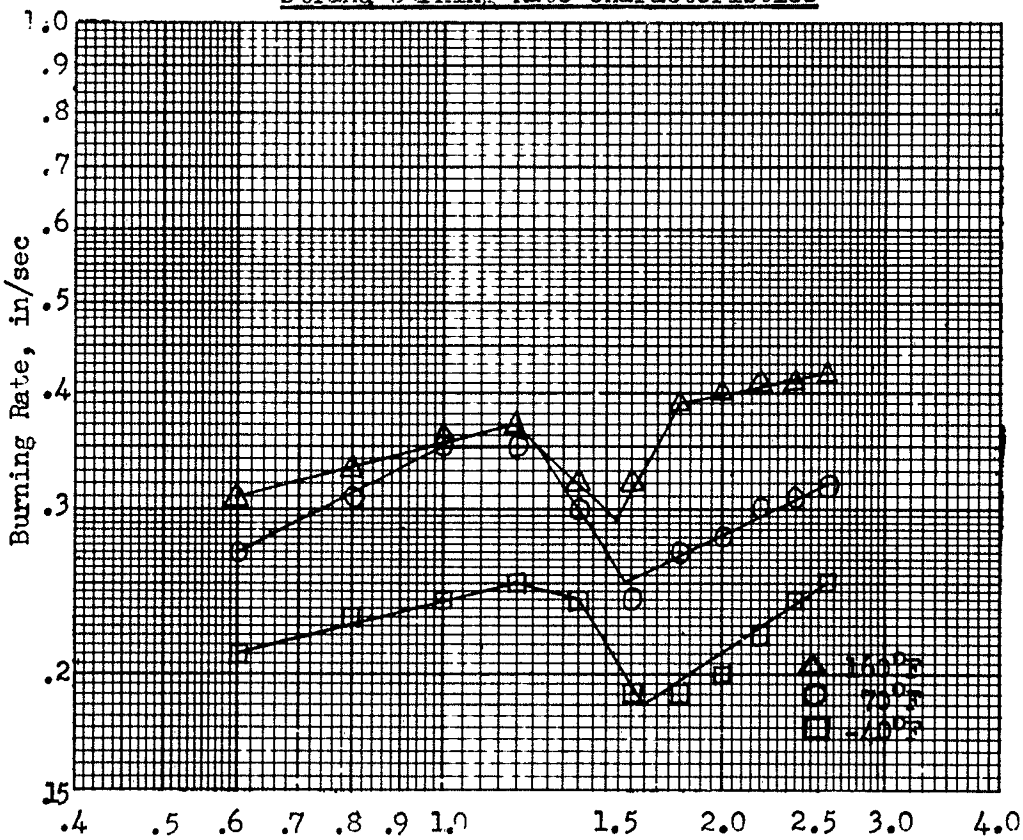
Propellant Data Sheet for Pilot Lot No. 335A

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	55.13
Nitroglycerin	27.5	27.57
Triacetin	13.0	13.44
Ethyl Centralite	1.0	1.04
4-Nitro-N-Methylaniline	1.0	0.92
Lead Stearate	2.0	1.90
Carbon Black (added)	0.03	0.11

*DuPont Lot No. 258B

Thermodynamic Properties	
Heat of Explosion, cal/gm	
Calc (Nom)	750
Expt	761
Calc (Anal)	741

Strand Burning Rate Characteristics



Pressure Exponent at 70°F	
Press Range, psi	Slope (n)
600-1000	0.51
1000-1270	0
1270-1570	-1.57
1570-2600	0.49

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1000	2860	0.25
1200	3450	0.23
1400	4650	0.11
1500	5550	0.24

Fugure 14

Propellant Data Sheet for Slurry 614 (T16 Propellant)

Composition, %	Nominal	Analysis
Nitrocellulose, 12.2%N*	55.5	55.09
Nitroglycerin	27.5	27.15
Triacetin	13.0	13.32
Ethyl Centralite	2.0	2.28
Lead Stearate	2.0	2.16
Carbon Black (added)	0.03	0.08

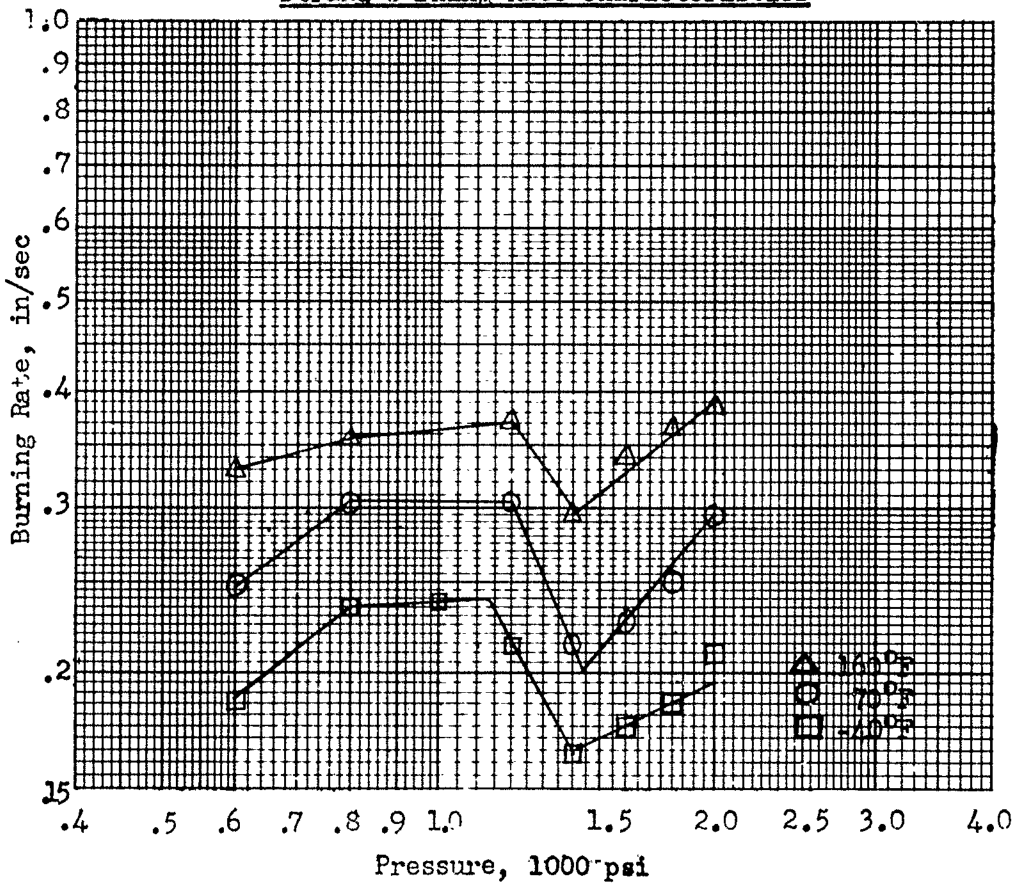
*DuPont Lot No. 3

Thermodynamic Properties

Heat of Explosion, cal/gm

Calc (Nom)	734
Expt	758
Calc (Anal)	708

Strand Burning Rate Characteristics



Pressure Exponent at 70°F

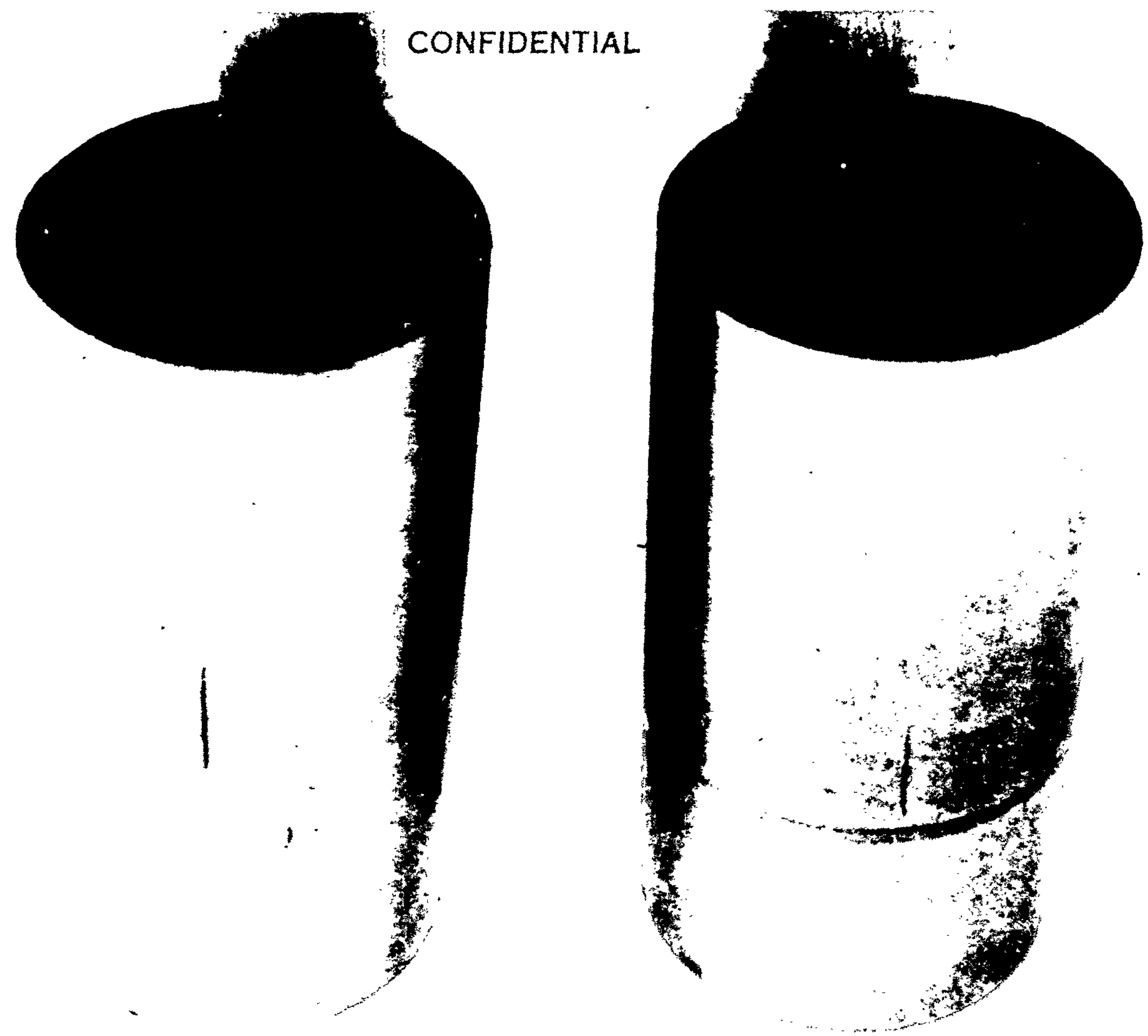
Press Range, psi	Slope (n)
600-800	0.69
800-1000	0
1000-1430	-1.18
1430-2000	1.14

Temp Coeff of Pressure at Constant P/r from -40°F to 160°F

Press at 70°F, psi	Ratio P/r	Temp Coeff, %/°F
1000	3280	0.26
1200	3890	0.16
1250	4550	0.11
1300	5050	0.23

Figure 15

CONFIDENTIAL

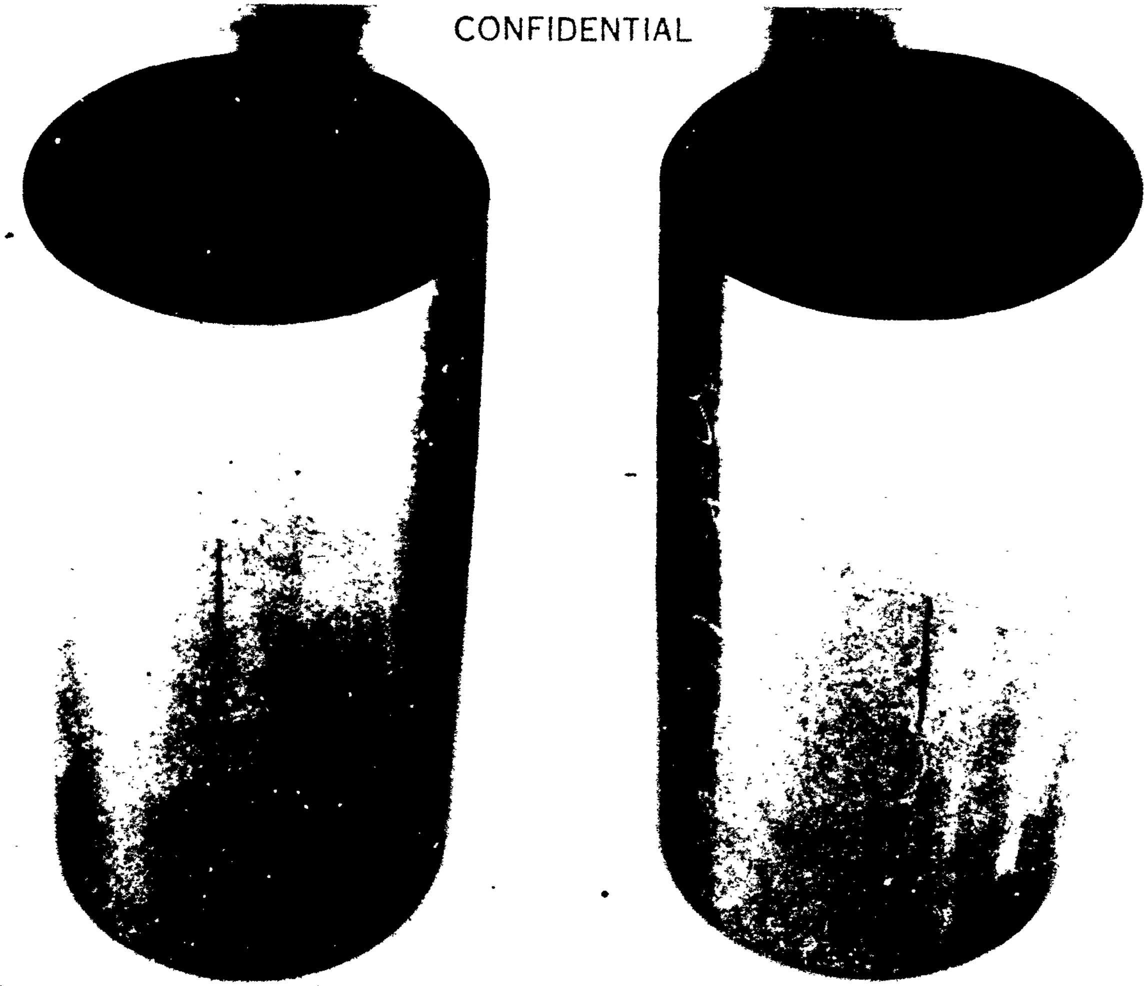


CONFIDENTIAL

M-42406/3 January 1943 PICATINNY ARSENAL ORDNANCE CORPS

Grains of Pilot Lot 334 After 11 Days Storage at 170°F
(5.0" OD x 1.0" ID x 10.0" long)

CONFIDENTIAL

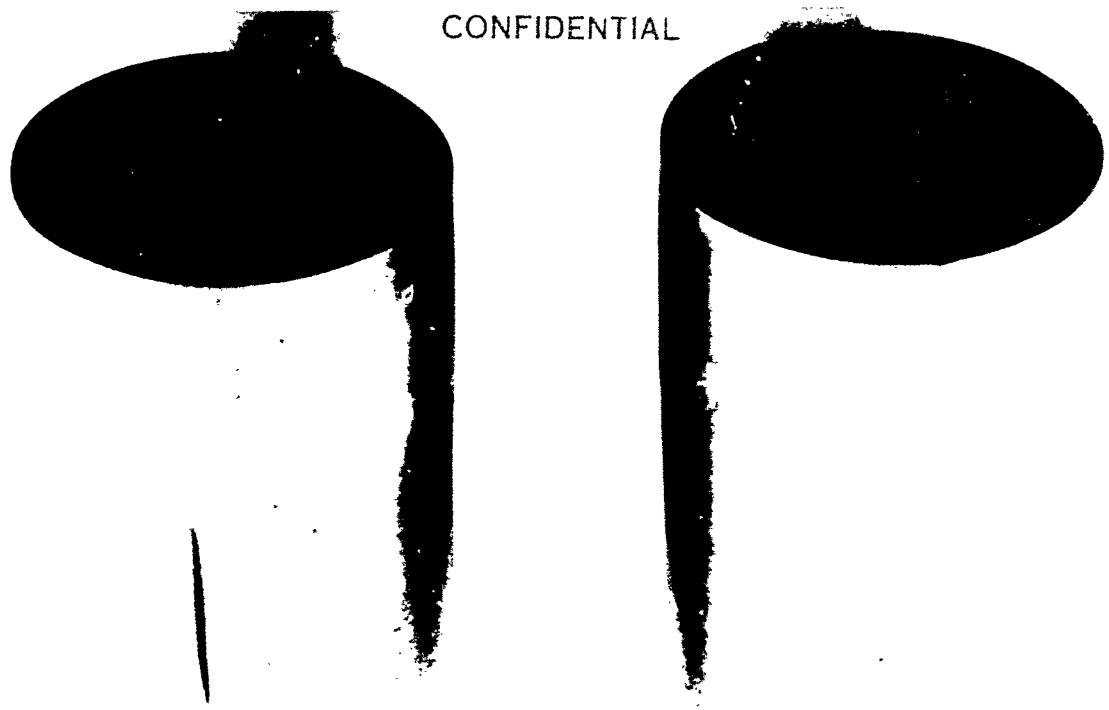


CONFIDENTIAL

M-42406/5 January 1953 PICATINNY ARSENAL ORDNANCE CORPS

Grains of Pilot Lot 335 After 1[illegible] Days Storage at 170°F
(5.0" OD x 1.0" ID x 10.0" long)

CONFIDENTIAL



CONFIDENTIAL

M-42406/1 January 1953 PICATINNY ARSENAL ORDNANCE CORPS

Grains of Pilot Lot 276B After 4 Days Storage at 170°F
(5.0" OD x 1.0" ID x 10.0" long)

CONFIDENTIAL

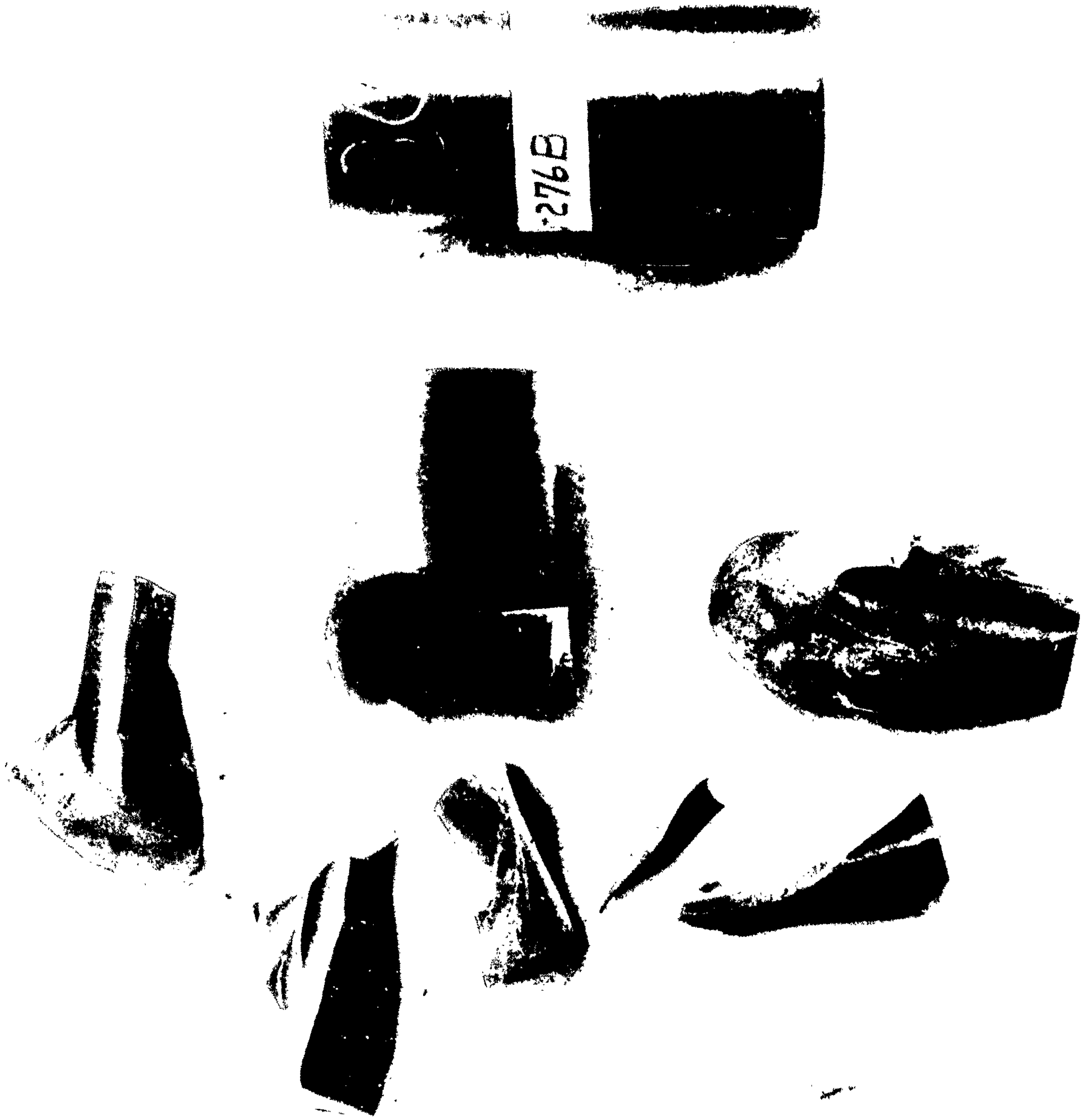
M-42931 May 1953 Picatinny Arsenal Ordnance Corps

Grains of Pilot Lot 334 which were shock cycled between -75°F and 170°F. (5.0" OD x 1.0" ID x 10.0" long).
Top Grain - 8½ cycles, initial temperature - 75°F
Bottom Grain - 7½ cycles, initial temperature 170°F
(24 hours at each temperature).

CONFIDENTIAL

M-4[illegible] May 1953 Picatinny Arsenal Ordnance Corps

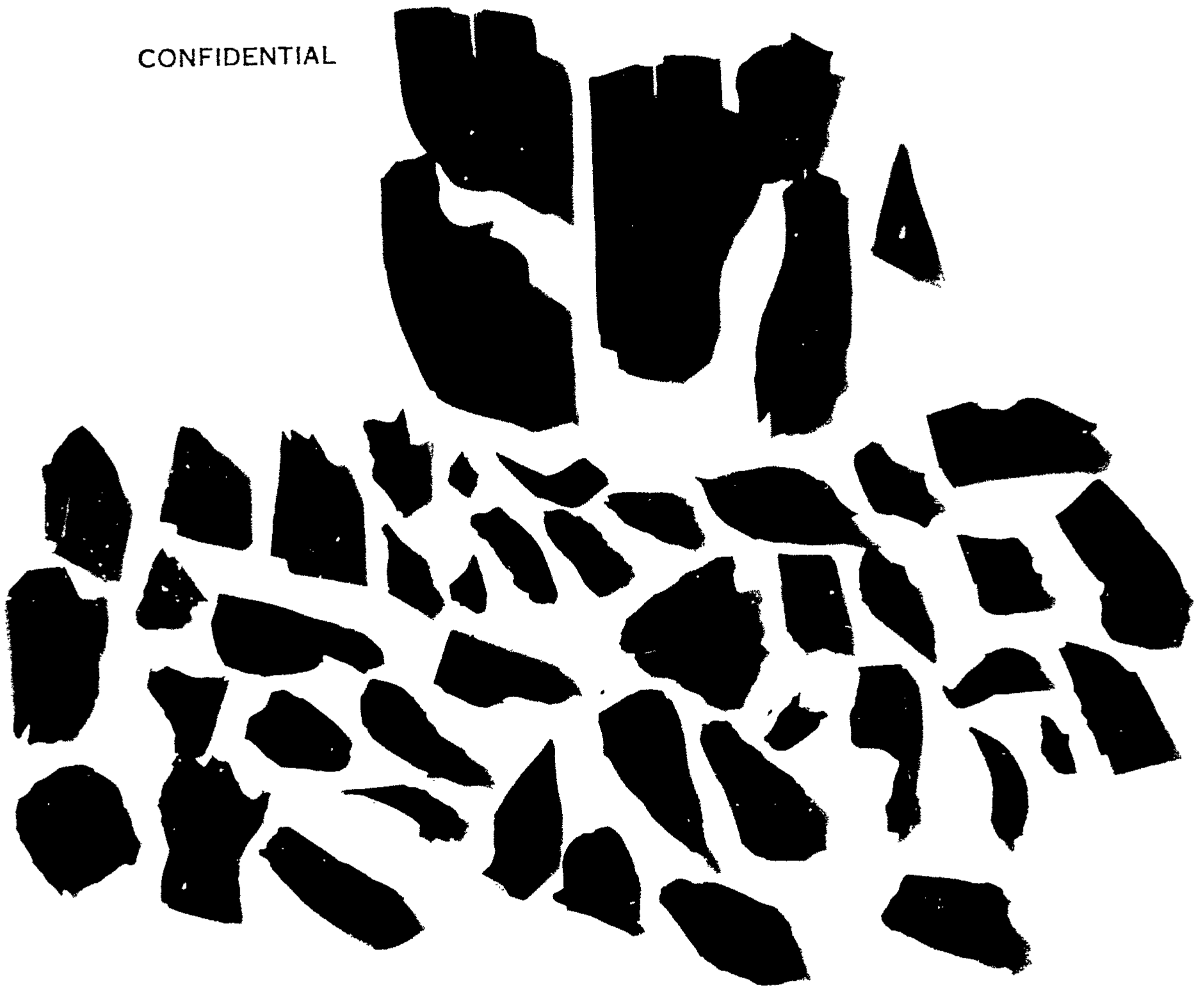
Grains of Pilot Lot 335 which were shock cycled between -75°F and 170°F (5.0" OD x 1.0" ID x 10.0" long).
Top Grain - 12 cycles, initial temperature 170°F
Bottom Grain - 11½ cycles, initial temperature -75°F
(24 hours at each temperature)



M-42[illegible]30 May 1953 Picatinny Arsenal Ordnance Corps

Grains of T19 Composition (Pilot Lot 276B) which were shock cycled between -75°F and 170°F (5.0" OD x 1.0" ID x 10.0" [illegible]). Top Grain - 4 cycles, initial temperature 170°F. Bottom Grain - $3\frac{1}{2}$ cycles, initial temperature - 75°F. (24 hours at each temperature).

CONFIDENTIAL



M-42932 May 1953 PICATINNY ARSENAL ORDNANCE CORPS

Grains of T-16 Composition which were shock cycled between -75°F and 170°F. (5.0" OD x 1.0" ID x 10.0" long). Top Grain - 7½ cycles, initial temperature -75°F. Bottom Grain - 10½ cycles, initial temperature 170°F. (24 hours at each temperature).

CONFIDENTIAL

DISTRIBUTION LIST FOR PA TECHNICAL REPORT NO. 2009

PROJECT NO. TU2-2C

	Copy No.
Commanding General Picatinny Arsenal Dover, N. J. ATTN: Technical Library	1-5
Chief of Ordnance Dept of the Army Washington 25, D. C. ATTN: ORDTA - Propellant and Primer Section	6
ORDTU	7
ORDTX-AR	8
Commanding General Aberdeen Proving Ground Maryland ATTN: Ballistic Research Laboratories	9
ORDBG-BLI	10
Commanding Officer Frankford Arsenal Bridge and Tacony Streets Philadelphia 37, Pa. ATTN: Pitman-Dunn Laboratory	11-13
Commanding Officer Office of Ordnance Research Box CM Duke Station Durham, N.C.	14-16
Commanding General White Sands Proving Ground Las Cruses, N. M. ATTN: Technical Librarian	17-19

	Copy No.
Dept of the Navy Bureau of Ordnance Washington 25, D.C. ATTN: Ad3, Technical Library	33
Re2a	34
Re2d	35
Dept of the Navy Office of Naval Research Washington 25, D.C. ATTN: Code 429	36
Commanding Officer U.S. Naval Powder Factory Indian Head, Maryland ATTN: Res and Dev Dept	37-38
Commander U.S. Naval Ordnance Laboratory White Oak Silver Spring 19, Maryland ATTN: Library	39
Commander U.S. Naval Ordnance Test Station Inyokern, China Lake California ATTN: Technical Library Branch	40-42
Commanding Officer Officer of Naval Research Branch Office 86 East Randolph Street Chicago 1, Illinois ATTN: LTJG M. C. Laug	43
Commanding Officer Officer of Naval Research 1030 East Green Street Pasadena 1, California	44

	Copy No.
Commanding General Redstone Arsenal Huntsville, Alabama ATTN: Technical Library	20-21
Dept of the Air Force Hq USAF, DCS/D Washington 25, D.C. ATTN: AFDRD-AR	22
AFDRD-AN, Maj. H.R. Schmidt	23
Commanding General Wright Air Development Center Wright-Patterson Air Force Base Dayton, Ohio ATTN: WCEGH-2	24
WCLPN-2	25
WCRRC	26
Commanding General Air Research and Development Command P.O. Box 1395 Baltimore 3, Maryland ATTN: RDDAP, Lt Col L. F. Ayers	27
Commanding Officer Badger Ordnance Works Baraboo, Wisconsin	28
Commanding Officer Radford Ordnance Works Radford, Virginia	29
Commanding Officer Sunflower Ordnance Works Lawrence, Kansas	30
Dept of the Navy Bureau of Aeronautics Washington 25, D.C. ATTN: SI-5	31
TD-4	32

	Copy No.
Dept of the Navy Bureau of Ordnance Washington 25, D.C. ATTN: Ad3, Technical Library	33
Re2a	34
Re2d	35
Dept of the Navy Office of Naval Research Washington 25, D.C. ATTN: Code 429	36
Commanding Officer U.S. Naval Powder Factory Indian Head, Maryland ATTN: Res and Dev Dept	37-38
Commander U.S. Naval Ordnance Laboratory White Oak Silver Spring 19, Maryland ATTN: Library	39
Commander U.S. Naval Ordnance Test Station Inyokern, China Lake California ATTN: Technical Library Branch	40-42
Commanding Officer Officer of Naval Research Branch Office 86 East Randolph Street Chicago 1, Illinois ATTN: LTJG M. C. Laug	43
Commanding Officer Officer of Naval Research 1030 East Green Street Pasadena 1, California	44

	Copy No.
Aerojet-General Corporation P. O. Box 296 Azusa, California ATTN: Librarian	45
Allegany Ballistics Laboratory P. O. Box 210 Cumberland, Maryland	46-47
Armour Research Foundation of Illinois Institute of Technology Technology Center Chicago 16, Illinois ATTN: Propulsion and Structures Research; Dept M	48
Bureau of Mines 4800 Forbes Street Pittsburgh 13, Pa. ATTN: Explosives and Physical Sciences Division	49
E. I. duPont de Nemours and Company 10th and Market Streets Wilmington, Delaware ATTN: W. F. Jackson	50
Hercules Experiment Station Wilmington, Delaware ATTN: A. M. Ball	51
Director Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena 3, California	52-53
Arthur D. Little, Inc. 30 Memorial Drive Cambridge 42, Mass. ATTN: W. A. Sawyer	54

	Copy No.
Naval Ordnance Research School of Chemistry University of Minnesota Minneapolis 14, Minnesota ATTN: B. L. Crawford, Jr.	55
Rohm and Haas Company Redstone Arsenal Research Division Huntsville, Alabama ATTN: Technical Director	56
Solid Propellant Information Agency Applied Physics Laboratory The John Hopkins University Silver Spring, Maryland ATTN: P. K. Reily, Jr.	57-61
Armed Services Technical Information Agency Document Service Center Knott Bldg Dayton 2, Ohio ATTN: DSC-SD	62-65
Thiokol Chemical Corporation Redstone Arsenal Huntsville, Alabama ATTN: Technical Director	66-67
Western Cartridge Company East Alton, Illinois ATTN: R. L. Womer	68
Phillips Petroleum Company P. O. Box 548 McGregor, Texas ATTN: Librarian, J. Wiss	69-70
Universal Match Corporation P. O. Box 191 Ferguson 21, Missouri ATTN: Res and Dev Division THRU: District Chief St. Louis Ordnance District 4800 Goodfellow Blvd St. Louis 20, Missouri	71